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THE BIRD GIANTS.

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OSTRICHES AND OSTRICH FARMS.

BY CHARLES FREDERICK HOLDER.

Among the big things which the State of California produces are ostriches. It has been found that the mild climate of southern California is remarkably well adapted for the purpose, and that ostriches breed and thrive as well here as in their native African haunts. The experiment was first tried by an Englishmen, Mr. Edwin Cawston, who, in 1885, bought fifty-two birds in South Africa. It was a hazardous experiment, as the big birds are extremely difficult and dangerous to handle; but forty-two were landed on American soil. From these pioneers the fine ostrich farm at Pasadena, Cal., has grown, which at present contains two hundred birds. Here one can study the history of these birds from the egg to the adult; and as the industry is now protected by an import duty of 20 per cent, the ostrich farm is on a sure financial basis and has become one of the paying American industries.

The Pasadena ostrich farm is beautifully situated among a grove of live oaks on the Arroyo Seco, between the cities of Pasadena and Los Angeles. The inclosure of several acres is divided into corrals in which the various classes of birds are seen. As we enter, the birds approach in droves with a queer mincing gait, ludicrous in the extreme. The ostrich impresses one as being the type of stupidity, posing as a very wise personage; its large body, small head and brain, constructed on economical principles, its enormous eyes, all carrying out the idea.

The birds are fearless and approach visitors, taking food from their hands. The correct thing to do seems to be to feed oranges, which are devoured whole, the diversion being mutual, as the orange presents a remarkable appearance as it passes down the long neck of the bird. The keeper, who tells us that he was once nearly killed by a bird, is a fund of information, and from him we learn all the secrets of running an ostrich farm. First, one must have the birds, which cost from one thousand dollars upward apiece in Africa; but, as they breed when they are three years old, there is a quick return.

There is a definite arrangement in the corrals. The best-feathered are selected and paired, space being left between the males, which fight and often kill one another. During the laying time, it is often dangerous to approach them, the males rushing to the attack, and, by a forward downward kick, producing a serious wound, often fatal. Horses and even men have been killed; and when the charge is made, the keepers find safety by lying flat on the ground.

The adult birds are magnificent creatures, standing seven feet high and weighing two hundred and fifty pounds. One of the interesting sights is to see them feed. They literally eat anything, according to the keeper, but are maintained on alfalfa. Among the extraordinary things that have been snatched from the hands of visitors and others and swallowed are nails, a gimlet, lighted pipes, a rolled newspaper. The writer once saw an ostrich snatch a bonnet from a lady's head and swallow it; but in this case a green veil that was the bonne-bouche caused the animal's death. With their food of alfalfa and vegetables, the birds are provided with broken shell for the lime, and quantities of pebbles, which they swallow to aid in grinding the food.

The breeding season, at which time we are fortunate in making our visit, is in early spring. The male bird now becomes very active and ugly. He rests his breast bone on the ground at some selected spot, and with his powerful claws throws the dirt away, turning round and round during the operation, until a shallow hole is the result, by courtesy a nest. In this work the female sometimes joins. When it is complete, the hen takes her place and lays an egg every other day. And what an egg it is! One would make an omelet for thirty men with moderate appetites, as one weighs three pounds and is equal to thirty hen's eggs. When twelve or fourteen eggs have been deposited, the birds scatter a little sand over them and begin the labor of hatching them, dividing their time with almost mathematical precision, and presenting a remarkable instance of the sense of responsibility in both male and female. The male takes his place at four o'clock in the afternoon and covers the eggs. At nine o'clock in the morning he is relieved with all the promptness of a sentinel by the female; and it is an interesting point to notice that at noon, though the male is off duty, he relieves the female for an hour, allowing her to take a rest and obtain food. This can be seen by everyone, as the nests are in the open corral, and nesting carried on for nearly six weeks.

If one could approach the eggs now in the absence of both birds, a curious tapping would be heard on the shells, called "telephoning" by the keeper. In a word, the chicks have arrived and are knocking for admission into the world. Some succeed in breaking out; others have to be assisted, and the hen will press gently upon them at such times and break the shell; then she will take the youngster in her bill and pick it out, shaking the bits of shell from it.

The baby birds are most attractive little creatures, covered with wiry, hairlike feathers and possessed of the greatest curiosity. They are at once taken from the parents and brought up by hand in nurseries especially arranged for baby ostriches. They are turned into a field of alfalfa during the day and at night kept in warm boxes or artificial mothers. For two or three days they do not seem to care to eat. Then they eat stones and bone crushed, and on the fifth day alfalfa, from now on growing rapidly, so that at the age of six months they are six feet high, having grown at a rate of a foot a month; after this the growth is slower.

The reason for taking the young from the mother is a purely business one, as the birds immediately build another nest, which they would not do if the young were left with them to rear; so instead of one brood a year the owner obtains seventy or eighty eggs from a single bird. In six weeks the chicks are tall and robust birds, beautifully spotted and rapidly becoming valuable commodities. At a year old they are valued at $150 a pair; chicks three to six weeks old, $40 a pair; while the full grown bird is valued at $300 per pair. It is evident then that the ostrich is within the reach of the average individual; yet there are some drawbacks, as an ordinary ostrich has an appetite that, apparently, has no limitations, and one will literally eat a poor man out of house and home.

The birds are valued for their feathers, for which there is a growing demand, and if the visitor is present at the farm during what is termed the "picking," he or she is well repaid. The full feathered bird is a beautiful creature, but every feather is not valuable or a plume. The feathers are of many kinds and differ widely. In the very young birds they are yellow and white, later dark drab on the male, black and white in the female. The fine plumes are found on the adult male and to bring the best price should be taken from the living bird, those from the wing being the most esteemed, especially the so-called ivory-colored plumes.

The picking of the feather crop occurs every few months, the occasion being not only interesting but exciting, as the birds protest decidedly to the robbery. The pickers are men skilled in the business; necessarily so, as poor picking ruins feathers and birds. When picked, the feathers are what is termed ripe; that is, they would soon be thrown off by the moulting process, consequently there is little or no pain in the operation. The heavy plumes are cut off, the stumps being removed three months later.

At this picking time the birds are separated and driven into a narrow pen, their heads being covered with a perforated bag. The men station themselves behind, so that the bird cannot kick, and holding it securely the picking is performed in view of the large audience that usually collects at this time. Three crops of feathers are obtained in about two years, each bird being estimated to produce $30 per year in feathers; and as each bird attains an age of from fifty to even seventy years, the profit of feathers alone is enormous, not to count the young. As the feathers are collected they are classified and placed in bags; those of the males in one, those of the females in another, as all have some peculiar market value, and the grades are well recognized by the trade.

When graded and weighed, they go to the expert feather dressers of Los Angeles, San Francisco, and New York. Here they are tied on strings four feet in length, or in bunches, classified thoroughly, and are then sent to the dyer, as no matter whether the feather is naturally black it is dyed black. After this they are washed in water and starch; the latter is then removed when they are ready for the "finisher," where they are graded, assorted, sewed together, often three or five pieces to make one plume; they are then steamed to allow the fibers to take their natural position. The curler now takes them, and gives the plume the graceful shape so desired. From the hands of the curler they pass to the man called the "buncher," who combs them out and gives them the particular shape demanded by fashion. Now the plume or feather is ready for the market and is placed on sale. The history of the feather from the hatching of the young ostrich to the beautiful plume on the hat of some lady is a long and complicated one.

The commercial side of the industry is not without interest. Birds are sold to circuses and shows; the unfertile eggs bring a dollar apiece as curiosities; the feathers are made into boas, which range from $3 to $35; capes, ranging from $16 to $25; fans, tips, single plumes, collarettes, and other objects, suggestive that ostrich farming must be a profitable business; indeed, in South Africa it was at one time ranked next to that of the diamond in point of value.

But the interest in the farm to the average visitor consists in the birds and their strange habits; whether bathing in the pool, or walking jauntily around the corral, or sailing along with outspread wings, they present a fascinating spectacle. The strength of the male ostrich has been the subject of many experiments at the Pasadena farm, and not the least interesting is the great bird used as a saddle horse, a boy mounting the steed and riding it about, the bird carrying its load with the greatest ease. The birds have also been harnessed and driven tandem, to the delight of the young people.

A visit to this farm corrects many errors that may have found place in the mind of the observer. The ostrich does not thrust its head in the sand to avoid its enemy, but boldly charges horse or man, though, sad to relate, a dog will demoralize the entire herd. This is because the ostrich knows that it cannot strike so small an animal. That the birds allow the sun to hatch their eggs is another fiction exploded by a visit to the ostrich farm. No hen displays greater solicitude than does this gigantic mother, who is constantly robbed of her chicks, never enjoys the pleasure of maternity, of leading her young about, but is kept nestling the year around. If allowed to care for her young, the mother ostrich proves to be a famous caretaker. She, the giant mother of the bird creation, exercises them all day long, forcing them to run and eat, and at night gives them shelter beneath her warm plumes.

Sand Dunes in New Zealand.—Dr. Cockayne gives an interesting account of New Zealand sand dunes, in an official report. The characteristic of a dune, as contrasted with a fixed hill, consists of its instability, due to the material of which it is composed, hence the facility with which the whole mass can be moved to a longer or shorter distance, according to the velocity of the wind. Dunes are most frequent along the sea coast, but some are also present inland. Owing to the inland movement of the coastal dunes, much valuable land has been lost, and the danger is yearly becoming more difficult to combat. The area now occupied by dunes is, roughly speaking, 290,000 acres in the North Island and 24,000 acres in the South Island. The dunes of western Wellington occupy an area of more than 90,000 acres, and extend for about 170 miles along the coast.

The formation of the sand of the dunes commences on mountain sides, where the action of frost, variations in temperature, etc., bring about disintegration of rocks; such broken-up material is transported by rivers to the sea, which it reaches in various degrees of fineness varying from boulders to fine sand. A certain amount of sand is also directly due to the erosive action of the sea. Sand grains of dunes are distinguished from ordinary river and sea sands in being thoroughly rounded, due to the rolling backward and forward in a dry state by wind.

The dune flora is remarkably uniform throughout New Zealand, owing to the soil factor proving to be of more importance than the climatic factor. The dunes of the Auckland Islands have a special flora of their own. Dune plants proper not only tolerate but benefit by a partial sand burial, and are highly specialized, being characterized by their great length of stem. This enables them to spread over wide areas, and to increase rapidly by vegetative means under conditions which would be fatal to seedlings. Among the most important of such "sand binders" are *Spinifex hirsutus*, a grass; *Scirpus frondosus*, a sedge; and *Euphorbia glauca*, a spurge. A few other plants usually present are of minor importance. It is very rare

indeed that a dune in course of formation is quite destitute of plant life; indeed, the majority owe their progress and existence to the presence of "sand-binding" plants, which in the first instance have stopped the sand drift, and assist further deposits to collect, while at the same time their own growth is accelerated, they and the sand rising up together. It is remarkable how scanty a plant covering checks the wind; even where tufts of grass or sedge are only a foot tall, and where more than two-thirds of the surface is unprotected, it is remarkably stable.

The author considers that judging from the results obtained in Europe, the great bulk of the sand dunes in New Zealand could be reclaimed. The final treatment of dunes should be afforestation.—Knowledge.

MENDEL AND THE ORIGIN OF SPECIES.

A NEW BIOLOGICAL LAW.

BY PROF. OTTO N. WITT.

It is a well-known fact that children whose parents differ greatly from each other exhibit the characteristics of both parents. Often, as in the case of domestic animals, this mixture of characters is so apparent that even inexperienced observers easily distinguish mongrels from animals of pure breed. The idea suggests itself that frequently repeated crosses must result in a form in which so many different characters are combined that it cannot be referred to any known type, but constitutes a new species, which can be kept constant in the future by preventing further crossing.

Some valuable breeds of animals have undoubtedly been produced substantially in this way. In general, however, no cross-breeding exerts such a decisive influence upon natural selection and the origin of species. This is the more remarkable because there is, apparently, nothing to prevent the crossing of wild animals, and crosses between widely-separated plants are promoted by natural agencies for the transport of pollen and natural obstacles to self-fertilization. As a matter of fact, the production of natural hybrids is an exceedingly common occurrence in the vegetable kingdom. It might be supposed that, in these favorable conditions for cross-breeding, all clearly distinguishable species must have vanished long ago. This is assuredly not the case, for, though the idea of species is a creation of the human mind, it is based upon observed facts, and it cannot be denied that, despite all variations, certain specific characters are transmitted unchanged.

To explain this paradox it has been suggested that hybrids are less prolific than pure species, and, consequently, soon disappear. This hypothesis is based chiefly on the sterility of the mule, the hybrid between the horse and the ass. But there are many hybrids which reproduce their kind indefinitely and, especially in plants, crossing may occur between very dissimilar types, though the progeny sometimes appears exactly like one parent and exhibits none of the special characters of the other.

Hence the permanence of hybrids cannot be explained by the absolute or comparative sterility of hybrids. Another explanation is based on the often observed appearance of characters, which are apparently inherited, not from the immediate parents, but from remote ancestors, as if the organism were striving to revert to its original type. Darwin observed this phenomenon, which he called atavism, but did not discover the laws that govern it. Much more was accomplished in this direction by the Austrian monk Mendel, whose researches were long neglected and have only recently received due appreciation.

Mendel's celebrated experiments in hybridizing peas are very ingenious and interesting, although they do not, in my opinion, possess the far-reaching importance which many biologists accord to them. They have the advantage over most experiments of the sort, that they can be performed within a comparatively short period.

By crossing a red-flowering with a white-flowering variety Mendel obtained peas which, when sown, produced, almost exclusively, plants with pink blossoms, which apparently represented a mixture of the floral colors of the two parents. But Mendel found it impossible to perpetuate the pink-flowering variety by self-fertilization, for each successive generation exhibited an increased proportion of reversions to the two original types, red-flowering and white-flowering, into which the pink variety was, finally, almost completely resolved.

Similar experiments, yielding similar results, have since been performed with other plants and with animals. The great diversity of colors exhibited by many flowers is known to result from the combination of a very few pigments. Attempts have been made to establish quantitative laws for the combination and the subsequent separation of these pigments. A new doctrine, Mendelism, has arisen and has already produced a literature, the copiousness of which suggests that it would be better, for a while, to make more observations and fewer deductions.

This biological phenomenon (like many others, as I have recently shown) bears a striking resemblance to certain phenomena of molecular physics. In a great number of instances, two chemical compounds when mixed together, produce a substance which exhibits the properties of both ingredients and which can be resolved again into those ingredients by appropriate treatment (for example, crystallization or fractional distillation). But, here also, the resolution is not effected at once, but successive intermediate products, containing continually increasing proportions of one or the other original constituent, are formed, and the complete separation is accomplished only after many repetitions of the process in which the tendency to separate is manifested. As the characters, chiefly colors, to which the observations of the Mendelists are confined, at present, are determined by the presence of definite chemical compounds (pigments) in the tissues, it is evident that a causal connection, and not merely a chance resemblance, exists between the chemical transformations described above and the changes in the colors of flowers and animals which are studied by the Mendelists.

Whether a complete knowledge of the nature of hybridization can be obtained from the observation of such changes in color is another question, and one which I regard as very doubtful. A pea vine or a variegated dog possesses a good many characters which are not necessarily connected. It is not even claimed that all of these characters appear or vanish together, and we are justified in expecting that they will not do so.

An example will make my meaning clearer. We will assume that peas, the favorite subjects of experiment, belong (which they do not) to a family of plants, of which some members are very poisonous and others are harmless. Let us suppose that white-flowering peas are harmless and red-flowering peas are poisonous. If the color is a certain indication of all other characters, the pink-flowering hybrid peas will be somewhat poisonous, and their continued propagation will result in the production of very poisonous red-flowering peas and perfectly harmless white-flowering peas. In these conditions, however, I would not have sufficient confidence in the infallibility of the Mendelian theory to eat abundantly of the white-flowering peas thus regenerated from the poisonous pink-flowering variety.

Mendelian experiments are not only so protracted that, in many cases, several generations of men would be required to complete them, but they also have the defect that the observation must be restricted to single characters, because it is scarcely possible to take cognizance of the entire process. From these observations of single characters many biologists draw conclusions of unwarranted generality.

Here, again, an example will make my meaning clear, and I will take the example from our own species, where it is most evident that a single character cannot serve as a guide to the rest. We will assume that a brother and sister, each having light hair, a phlegmatic disposition and special talent for mathematics, marry a sister and brother, who have red hair, quick tempers and great musical gifts. We will grant to the children of both marriages all these characters in various proportions, but can we imagine that if these children intermarry and their descendants intermarry for many generations the last generation will consist exclusively of blond, phlegmatic mathematicians and of musicians of fiery hair and temper? Does not experience lead us to expect at least a few blond musicians and red-haired but phlegmatic persons?

Many experiments in cross-breeding fail to yield results in accordance with Mendel's laws. Albinism, or the absence of the normal pigmentation, is very common in both animals and plants. The offspring of two parents, both of which are albinos, might be expected to inherit this striking peculiarity, but this is not always the case. Albinism is very common among orchids, and pure white orchids are especially prized and diligently sought. But while the progeny of some albino orchids resembles their parents, the seedlings of others bear, without exception, deeply-colored flowers. Possibly a tendency to albinism would ultimately appear in the descendants of these colored hybrids of white orchids, but who has time to carry on a Mendelian experiment in which eight years are required for the maturing of each generation?

Hybridization unquestionably plays some part in the production of new species, but this part is neither so important as superficial observation often suggests, nor so insignificant as it is made to appear by unwarranted generalization of Mendel's observations. The origin of species is a very complex phenomenon, dependent on the co-operation of many causes, and we shall wait long for its complete explanation.—Translated for Scientific American Supplement from Prometheus.

HOW THE BODY PROTECTS ITSELF AGAINST MICRO-ORGANISMS.

How is it, if the air contains floating in it the dried spores of multitudinous micro-organisms which only need a suitable medium for their development and increase, how is it that they do not obtain a lodgment in the healthy animal body, which one would think offers all the conditions necessary to their growth? It can easily be shown that the air we breathe, the water we drink, the food we eat, everything that we touch, swarms with these microscopic creatures; that they enter our lungs, that they germinate in our skin, that they occur in countless numbers in our alimentary canals, in short, that they are found everywhere on our body surfaces. How is it that they do not increase and turn our organs into a seething mass of putrefying corruption? One would expect that even if the skin and the membrane bounding the internal organs to which they obtain entrance incurred the slightest lesion, even a pin prick, that they would have been able to enter. We know that after death they at once obtain complete dominion, and we therefore infer that in life there must be some protective mechanism in the body capable of dealing with them.

The discovery that there is such a mechanism was made in the early eighties by the distinguished Russian zoologist Elias Metschnikoff, though the need of its existence was not recognized by biologists in general until later. The result of this was that his remarkable discoveries were at first pooh-poohed and discredited by many, but ultimately they gained acceptance, and their further development in his own hand and that of others has wrought a revolution in the art of preventive medicine.

The mechanism consists of the small amœboid cells found in the blood, lymph, and body fluids generally, and called leucocytes, or white blood corpuscles. Though long known to exist, very little had been ascertained as to their function until Metschnikoff, working at such remote subjects as the embryology of sponges, the structure and digestion of polyps, the blood of water fleas, realized that these small amœba-like cells, which exist in all organisms, actually swallow, digest, and so destroy small foreign bodies which have invaded the organisms. He called them the phagocytes, and all his subsequent work has been directed to the elucidation of their mode of action.

It is to Metschnikoff's work, prompted solely by the scientific spirit, that we owe our knowledge of phagocytosis and the great theory of immunity which has proceeded from it. It is impossible at the present moment to estimate fully the value to man of Metschnikoff's discoveries. Suffice it to say that they have already led to important practical results.

Application was recently made for protection of an invention to produce ammonia from the atmosphere by means of aluminium. Nothing is yet known of the details of the process, but from the titles of the three applications it is gathered, says the Chemical Trades Journal, that the aluminium and nitrogen are first caused to combine to form nitrides of aluminium which afterward are converted into ammonia.

AN INTERNAL-COMBUSTION PUMP.—I.*

APPLICATIONS OF A NEW PRINCIPLE.

BY HERBERT A. HUMPHREY

Pumps play such an important part in every branch of engineering that no apology is needed in bringing before the notice of this Institution a construction of pump based upon entirely new principles. Every engineer is familiar with pumps driven mechanically or by steam, and recently there has been considerable development of pumps driven by gas engines. The South Staffordshire Mines Drainage Commissioners, for instance, have replaced steam engines by gas engines in five of their pumping stations, with very beneficial results, the change having led to a considerable economy of working.

Compound condensing direct-driven steam pumps of modern construction and large size are among the most economical of all steam-using plants, and under favorable conditions will give a pump-horse-power hour for an expenditure of 18 pounds of steam. But at the other end of the scale we have the direct-acting steam pump generally working with very little or no expansion. Such pumps are notoriously uneconomical, and frequently use 70 pounds to 150 pounds of steam per pump-horse-power hour. It is only the extreme convenience and simplicity of such pumps that induces engineers to tolerate their low efficiency.

Fig. 1. DIAGRAM OF THE FIRST EXPERIMENTAL FOUR-CYCLE PUMP.

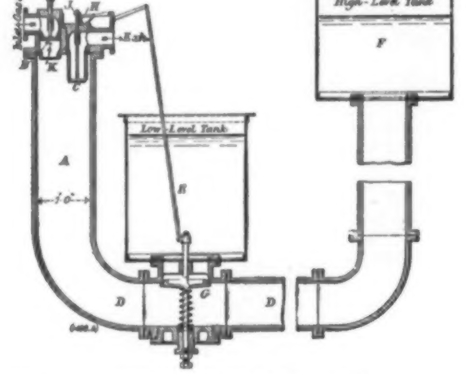


Fig. 2. COMPRESSION PRESSURE DUE TO A LIFT EQUAL TO 60 LBS. PER SQ. IN.

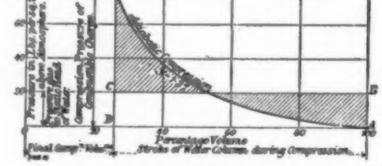


DIAGRAM ILLUSTRATING METHOD OF ALTERING PERIODICITY BY ALTERING LENGTH (FOUR AVAILABLE) OF DISCHARGE PIPE.

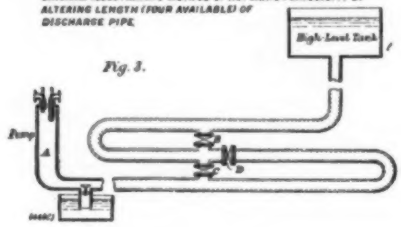


Fig. 3.

IGNITION APPARATUS FOR FIRING AT MAXIMUM COMPRESSION PRESSURE.

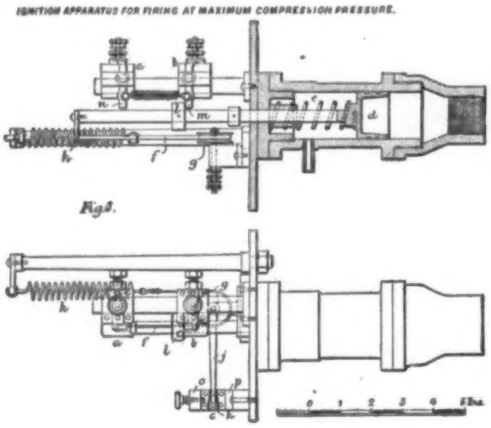
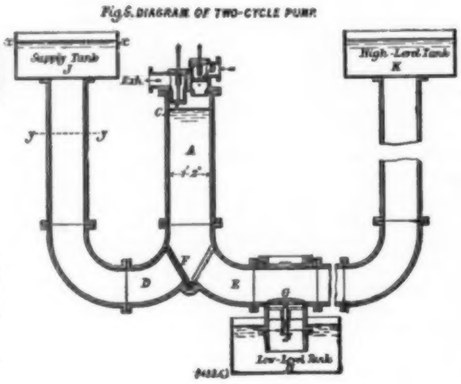


Fig. 4.

Fig. 5. DIAGRAM OF TWO-CYCLE PUMP.



Economy of fuel is undoubtedly obtained when an internal-combustion engine is used to generate the power for driving a pump; but by the time the mechanical efficiency of the gas engine and the intermediate gearing is taken into account, one finds that the economy is considerably discounted, and such a combination of gas engine and pump can never be regarded as a final solution of the problem.

The author's aim has been to produce a pump of great simplicity and strength of construction, in which the explosive force is exerted directly upon the water, and in which no rotating flywheel, solid piston, connecting rod, crank, bearings, or glands of any sort are required; and as the results of his experiments several very successful types of pumps have been invented and set to work on a sufficiently large scale to demonstrate their utility and economy.

The idea of exploding a combustible mixture of gas and air to produce pressure on the surface of water, with the object of raising the water, is, of course, not new, and attempts to put this idea into practice date back to 1868. The efforts have all been directed too much along the lines of ordinary pumps insofar that the water lifted has always been forced past a non-return valve, and the operation of such a valve with the explosive force behind it has been inevitably disastrous. In the types of pumps invented by the author there is, when the explosion occurs, a full-bore passage from the combustion chamber to the final outlet, also some of the water pumped to a high level by the energy of the explosion is allowed to return again to compress a fresh combustible charge. When sudden changes of velocity occur in masses of a heavy and incompressible liquid, like water, great difficulty is found in controlling the movement of the liquid. All such difficulties are removed in the author's pumps by allowing the movements of liquid to control the pump, and by causing the mass of liquid moved to be sufficiently large, so that the velocities are never excessive. The mass of water forms a pendulum which swings between the high and lower level, and, by its movement alone, serves to draw in fresh water, to exhaust the burnt products, to draw in a fresh combustible charge, and to compress the charge previous to ignition. With the movements of the liquid quite unrestrained by any of the usual mechanical appliances, the result is a pump which works with freedom from shock and noise, and which requires very few working parts.

The subject attains a wider scientific interest from the fact that the apparatus follows a cycle in which the expansion of the burnt products is carried to atmospheric pressure, and so involves a thermodynamic cycle of greater efficiency than can be claimed for the Otto cycle. The underlying principles of the invention are capable of application in many useful directions besides that of raising or forcing liquids, and are especially adaptable to the compression of elastic fluids.

The researches and experimental work, which have occupied three years, constitute an attack upon the gas pump, gas turbine, and gas engine problems, and these three have been so closely associated in the author's mind that it is almost impossible to treat the gas pump as a thing apart. It seems natural and proper, therefore, to present the general scientific aspect of the problem first.

Every text-book which deals with the theory of the gas engine contrasts the theoretically perfect indicator diagram with diagrams obtained in actual practice. There is no gas engine on the market working on a cycle which permits expansion of the ignited gases to be carried beyond the original suction volume. As a consequence, when a gas engine is working at full load the exhaust gases are rejected at a high temperature, and at a pressure of between two and three atmospheres. The energy thus wasted is a considerable percentage of the total energy converted into work, and we must put this waste down as an inherent defect in all existing types of gas engines. The requirements for a perfect cycle are as follows:

1. The suction stroke taking in the combustible mixture.
2. The compression stroke, the length of which is dependent upon the compression pressure desired.
3. The working or expansion stroke, which should be much longer than (1) in order to fully utilize the work of the expanding gases.
4. The exhaust stroke, which is another long stroke comparable with (3), but the exact length of which depends upon the clearance space.

All four strokes will be of unequal length, and a perfect gas engine should be capable of meeting these conditions.

Again, theory indicates that for great economy we must have high temperatures, and in practice we know that at such temperatures it is impossible to lubricate the piston unless the cylinder walls are cooled. The larger the diameter of the cylinder the thicker must be the walls of the cylinder to resist the bursting pressure, and the more difficult it becomes to conduct away the heat fast enough. Experiments have shown that with the largest cylinders now in use, having a thickness of, say, 4 inches of metal, the limit is nearly reached, so that if cylinder walls be made much thicker the lubricating oil would be burnt up and pre-ignition trouble would arise, even with a good circulation of cold water on the outside of the cylinder. Perhaps the chief difficulties which designers of large gas engines have had to meet are those arising from expansion and contraction of the cylinder and piston, which have necessitated somewhat complicated arrangements for cooling the latter by circulating through it high-pressure water, and the use of a large water jacket in connection with the former. Broken cylinder-covers, jacket castings, and cracked pistons are not nearly so common now as they were, thanks to the great ingenuity and skill displayed in their design; but the necessity for meeting expansion at all points has not tended to simplicity in the modern gas engine. Some years ago the author carried out experiments with a Vogt gas engine and the trials showed that internal cooling, arising from the use of a water piston, was consistent with a high thermal efficiency. It seems logical, therefore, to conclude that at least in large units the outside water jacket will be dispensed with, and internal cooling substituted, and the ideal engine should possess this method of internal cooling.

Let us now for one moment consider the actual construction of the gas engine as it exists to-day. We find a solid piston with its water-cooling arrangements its piston rings, its piston rod, and somewhat expensive type of gland packing, and the usual connecting rod, cross head, and guides, and then the crankshaft and flywheel, with the massive bearings, lubricating devices, and strong framework. If we take the Otto engine as the simplest type of engine, and which often dispenses with the piston-rod, we yet have the two-to-one gearing with the side shaft carrying the cams to operate the necessary levers and valves. How much of all this is really necessary? In answering this question a list of the actual essentials which a gas engine must possess may be made out as follows: A working cylinder, an inlet valve for combustible mixture, an exhaust valve for burnt products, a flywheel, and an ignition device.

Obviously the numerous things which belong to a gas engine outside of these essentials would readily be dispensed with if it were possible to do without them, and we should then arrive at a gas engine in which the energy was delivered direct to the flywheel without any intermediate gearing. To retain this degree of simplicity the flywheel would also have to fulfill the functions of a piston which draws in a fresh combustible charge and compresses it in the cylinder. If we imagine everything discarded which first principles do not demand as necessary, our ideal engine will have the following properties and parts:

1. It must be capable of four unequal strokes.
2. It must utilize the whole possible range of expansion down to atmospheric pressure.
3. The energy must be delivered direct to the flywheel without any intermediate parts.
4. There must be internal-cooling arrangements, so that the cylinders may be made of any size within the limits of structural possibility.

* Paper read before the Institute of Mechanical Engineers.

5. There must be an ignition device, but, as there is no two-to-one shaft to operate it, it must be entirely automatic and depend only upon the compression pressure having reached a maximum.

6. Difficulties connected with contraction and expansion must be eliminated.

These conditions may look sufficiently impossible, but the ideal engine must not only fulfill them, but must be capable of meeting other requirements. Thus, it is surely not wise to take in a whole cylinderful of mixture when the output of the engine is only a fraction of its maximum; all the strokes should be shortened up when the call for power is less, assuming, of course, that the number of strokes per minute are to remain constant, which is generally the case.

Having evolved our conditions for an ideal engine from first principles only, the question is, How far can a practical machine be made to meet these conditions? So far as a prime mover on these lines is concerned, the author believes that a practical solution can be found, but the following considerations tempt him to depart from a direct solution.

Granted that water is needed for internal cooling, then surely it is better to use a water piston. If this piston is made heavy enough, it may well serve as a flywheel, but it will be a reciprocating instead of a rotary flywheel. Here, then, the temptation to extreme simplicity comes in. Let us for the moment abandon the idea of a prime mover with a rotating the exhaust valve. Suppose all the valves shut and a compressed combustible charge to exist in the top of the combustion chamber. The rest of the chamber and the pipe are full of water. Explosion occurs at a sparking plug *K*, and the increase of pressure drives the water downward in the chamber and forces the column of water contained in the pipe to move toward the high-level tank, so that a quantity of water is discharged into this tank. From the moment when ignition occurs to the time when expansion reaches a pressure equivalent to the static head of the water in the high-level tank, the excess pressure in the combustion chamber has been increasing the velocity of flow toward the high-level tank, so that at the end of this period the column of water has a considerable velocity. The kinetic energy thus acquired causes the water to continue to flow in the same direction, until the pressure on the under side of the water valve is less than that above the water valve, and the difference of pressure causes this valve to open.

This occurs when the products of combustion have expanded to about atmospheric pressure. The opening of the water valve releases the exhaust valve, and now water from the low-level tank flows past the water valve partly to follow the column of water still moving toward the high-level tank, and partly to flow into the combustion chamber to expel some of the exhaust gases. There is, of course, a tendency for the namely, to a level in the combustion chamber a little below the level of the water in the low-level tank, but it actually does not move quite so far. However, when the water passes the level of the exhaust valve the elastic cushion is again at atmospheric pressure, and the further descent of the water in the combustion chamber tends to create a vacuum, but the inlet valve is only held shut by a light spring, and can therefore readily open to admit a fresh combustible charge during the rest of the descent, and until the water column is once more at rest. The state of affairs now reached is, of course, still unstable, because of the unbalanced pressure due to the head in the high-level tank, and this head produces a second return of the column, so that water ascends in the combustion chamber and compresses the fresh combustible charge. The explosion of the charge by means of the ignition plug now starts a fresh cycle. The operation of the apparatus is so simple that when an actual apparatus on these lines was first tried it ran steadily at the very first attempt.

Although the apparatus just described looks so simple, yet the calculations required in studying the complete working conditions are very complicated. Up to the present the author has not been able to express the results of calculations in any general formula including all the variables involved. Integration on a time base is the only method so far used to follow out the conditions through a complete cycle. It is not,

Fig. 6. DIAGRAM OF MODIFIED TWO-CYCLE PUMP.

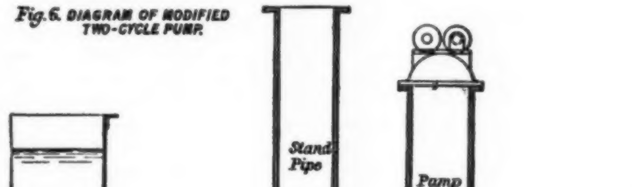


Fig. 7. DIAGRAM OF DOUBLE BARREL TWO-CYCLE PUMP.

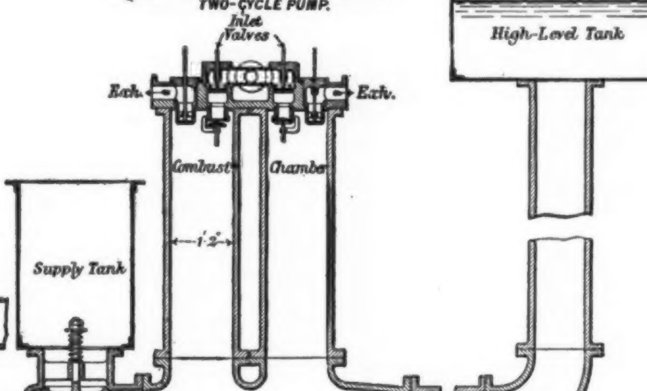


Fig. 8. FIRST EXPERIMENTAL TWO-CYCLE PUMP. (1906).

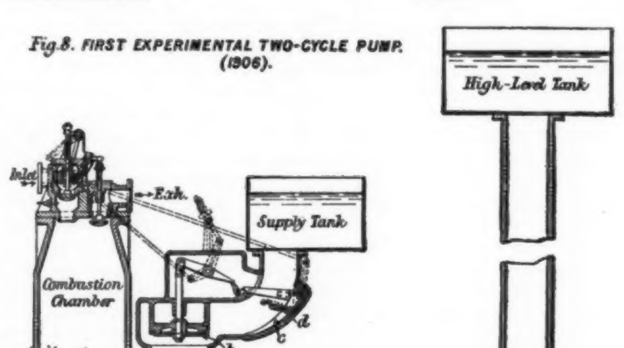


Fig. 10. DIAGRAM OF A PUMP USED FOR DRIVING AN AIR-COMPRESSOR.

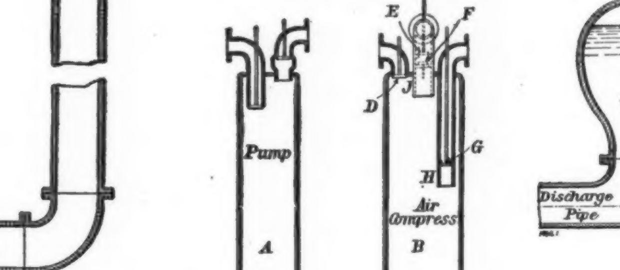
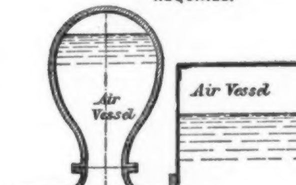


Fig. 9. ADDITION AT END OF DISCHARGE PIPE WHEN HIGH LIFTS ARE REQUIRED.



shaft, and allow our water flywheel to so reciprocate that at each working stroke it leaves a quantity of water at a higher level or pressure. This only requires the fitting of a single water valve, but our final apparatus then becomes a pump instead of an engine, and our gas power appears as water power.

The arguments and conclusions having been stated, we are in a position to proceed with a description of the apparatus employed by the author in carrying out the principles involved. It should, however, be mentioned that the order in which the different types of apparatus are here described is chosen for logical sequence, but is not that in which they were actually invented.

Fig. 1, page 100, is a diagram of one of the simplest forms of construction. It consists essentially of a combustion chamber *A* fitted with an inlet valve *B* for combustible mixture, and an exhaust valve *C* for burnt products. A pipe *D* connects the bottom of the combustion chamber to a low-level tank *E* and to a high-level tank *F*, and between this pipe and the former there is a water valve *G*. The inlet valve *B* is normally kept shut by a spring, but the exhaust valve *C* has no spring to hold it up, and falls by its own weight when pawl *H* is removed from under a collar *J* fastened on the exhaust-valve stem. This pawl is operated from the water valve *G* in the simple manner shown, so that when the water valve opens it releases water to rise in the chamber to the same level as the water in the low-level tank; but usually a little before this level is quite reached the kinetic energy of the moving column has been expended in forcing more water into the high-level tank, and the column has therefore come to rest. At this point of the cycle the spring on the water valve quietly closes this valve, and is assisted by the water now trying to flow back from the high-level tank to the chamber. It cannot flow back far, because there is already a considerable quantity of water in the chamber, and as the column rises further it reaches the exhaust valve, and, striking against it, shuts it by impact. The exhaust valve is immediately locked shut by the pawl shown engaging under the collar of the valve stem, and now that there is no longer any outlet for the small quantity of burnt products which remain, they are imprisoned in the top of the chamber and suffer compression as the water continues to rise, until the energy thus stored in the compressed elastic cushion is equivalent to the energy given out by the falling water. Thus the elastic cushion serves to bring the column of water again to rest; and as the compression pressure considerably exceeds the static head of the water column, a reverse flow is set up while this cushion expands again. If there were no friction losses, the water column would be forced back by the cushion to the same point as that from which it started— therefore, intended to deal fully with the theory of the pump, but some general observations will be of service.

Height of Lift.—In the first place it will be observed that the quantity of water delivered considerably exceeds what might be described as the stroke of the pump, or the change in volume of the gases from the time they are ignited until they expand to atmosphere. This is due to the water entrained from the low-level tank to follow the moving column of liquid going to the high-level tank. Consequently, if an indicator diagram could be obtained and the mean pressure of the stroke calculated, such pressure must be in excess of the equivalent pressure due to the head against which the water is raised. The burnt gases always expand down to atmosphere, therefore their mean pressure is less than that obtained in an Otto cycle gas engine since the stroke is so much greater, and, as a result, the head against which the water is lifted is limited to some 35 feet to 40 feet in most cases. This limitation is, however, entirely overcome by one or other of several arrangements to be described later, which enables water to be raised to practically any pressure which may be required.

Length of Pipe.—The length of pipe between the combustion chamber and the high-level tank must be sufficient to contain such a mass of water that its kinetic energy at maximum velocity shall insure the

burnt gases being expanded to atmosphere. This is the limiting condition, but the pump will work with any greater mass of water. If we fix 10 feet or 12 feet per second as the maximum velocity, then the smallest quantity of reciprocating water can be calculated for a given set of conditions. Theoretically, a comparatively short pipe of large diameter is better than a long pipe of smaller diameter, for not only can larger quantities of water be pumped without exceeding the maximum velocity of flow, but the time of a cycle is less with the short pipe. With a given difference of pressure between the two ends of the column, the acceleration is the same per unit of cross-section for all diameters of pipe of the same length, and a given volume of ignited gases can therefore expand to atmosphere in a shorter time when the delivery main is of a larger diameter. In the pumps so far constructed the diameter of the delivery main has been made almost as large as the diameter of the combustion chamber, if the latter is of cylindrical form. The periodicity of the cycle also depends on the length of the discharge pipe, and lengthening the pipe reduces the number of cycles per minute. It is found in practice that as the head against the pump increases, the minimum length of the discharge pipe must also be increased, so as to allow time for the water from the suction tank to rise in the combustion chamber before the column in the discharge pipe returns.

Supply Tank.—Since the volume of combustible mixture drawn into the combustion chamber is partly dependent upon the level of water in the supply tank, any alteration in this level affects the working of the pump and affords one simple method of regulating the amount of energy developed at each cycle. Thus, by raising the level of the water, smaller charges are drawn in, and, conversely, by lowering the level larger charges result. A float controlling the inlet to the supply tank may thus be used to regulate the output and power.

Compression Pressure.—The thermal efficiency of any apparatus deriving its energy from the expansion of an ignited combustible mixture depends upon the pressure to which the mixture is compressed before ignition; therefore high compression pressures are desirable within certain limits. The fact that the column of liquid which returns to compress the fresh combustible charge in the pump attains velocity in so doing, and then has its kinetic energy transformed into pressure energy, is most useful in this respect, for it enables compression pressures to be used greatly exceeding the static pressures due to the head of water which causes the return flow. Fig. 2 will serve to make this clear. If the ordinate $A\,B$ represents the pressure due to the static head of water, and if $A\,D$ represents the distance through which the column of water moves while compressing the charge, the work done is represented by the rectangle $A\,B\,C\,D$. An equivalent amount of work must be stored in the compressed gases, but as their pressure was only that of the atmosphere at starting, their final pressure will be at E, so that the area $A\,E\,D$ is equal to that of the rectangle, and the two shaded areas are equal to one another.

As the compression pressure is raised, the average pressure throughout the stroke is also raised, which means that the pump can deliver water against a greater head, but the greater head causes a greater compression pressure, and hence the pump is largely self-regulating. Thus, if called upon to pump against a greater head, the compression pressure automatically rises, and brings about conditions favorable for the increased work it has to do.

Cushion Space.—The volume of the top of the combustion chamber, above the level of the exhaust valve, forms a clearance space comparable with the clearance space of an ordinary Otto cycle gas engine, and the products of combustion which remain in this space are mixed off with the fresh combustible charge, and thus dilute this charge. This fact limits the amount of the clearance space in its relation to the charge volume, and if this proportion is kept at about the same as in gas engines—namely, about 20 per cent—then it happens that, as the head against which the water is delivered increases, the maximum cushion pressure may rise above the explosion pressure. This is specially the case if a pump, designed for using small charges, is worked with large charges of combustible mixture, since this is equivalent to reducing the clearance-space ratio. Although an astonishing amount of elasticity in working condition is possible, yet it is desirable to overcome any objection which may be raised on account of the high cushion pressure. This can be done in a very simple way by making the clearance space much greater than in an Otto cycle engine and using an effective scavenging device, so that practically pure air exists in the clearance space, and the combustible charge drawn in can then be richer in gas.

The clearance space being enlarged in this manner enables the requisite energy to be stored in the cushion at a lower maximum pressure.

Scavenging.—Positive scavenging arrangements, when applied to gas engines, involve the use of pumps of some kind, and therefore add to the number of parts and to the complication of the apparatus. In the author's pump scavenging is a very simple matter, as it is only necessary to insure that there is sufficient inertia in the water on the supply side to prevent this water flowing so quickly into the delivery pipe as to meet the full requirements of the moving column, and the result is at once to cause the moving column to draw part of its water supply from the combustion chamber and thus lower the level therein. Then, instead of exhaust products flowing outwardly past the exhaust valve, when the exhaust first opens, air will be drawn in past this valve, and later, when the water rises in the chamber, to drive out the burnt products, it will leave a mixture of air and products in the cushion space. This, in fact, is what happened in the first pump constructed, for however close the supply tank may be to the delivery pipe, there is enough inertia to produce the effect. If a long exhaust pipe is used to conduct away the burnt gases, these gases alone would be drawn back, and, as it is not desirable to work without an exhaust pipe, the scavenging effect can be turned to much better advantage by introducing a special scavenging valve and giving the combustion chamber a suitable shape, and this has been done in later constructions.

Operation of the Valves.—All three valves being at liberty to move, so soon as there is any difference of pressure to move them, open and shut quietly unless the speed of working is allowed to become too great. The shutting of the exhaust valve by the impact of water upon it was not expected to take place with such absolute certainty and precision as is actually found; indeed, the exhaust valve was not originally designed as a simple valve, but when this simple form was tried, it worked so well that its adoption now forms one of the features of the pump.

The suction which produces scavenging also tends to open the inlet valve, Fig. 1, and draw in some combustible gases which might then be wasted by passing away in the exhaust. This can be prevented by tightening up the spring on the admission valve, but this method involves frictional losses in drawing in the charge. This difficulty, and also the necessity for some connection for operating the exhaust valve from the water valve, is obviated by the introduction of a new design of valve gear, which is described later; and in pumps as now constructed the inlet and exhaust valves mutually control one another, so that no connection with the water valves is wanted.

Starting, Stopping, and Controlling.—In first starting the pump all that is necessary is to allow a charge of compressed air to flow into the combustion chamber, and so depress the water level a little below the usual charge volume. If the exhaust valve is now forcibly opened, the water will rise in the chamber, close the exhaust valve, and give the cushion and charging strokes. The charge drawn in is then fired and the pump starts working. If the pump is at work, and it is desired to stop, it is only necessary to switch off the current which operates the sparking coil. The pump then stops, with a charge of unexploded mixture in it, and can at any time be started again by merely switching on the current. Such simple and instantaneous means of starting and stopping enable the pump to be controlled from a distance; in fact, it can be operated from a switchboard at any convenient place.

The general methods of controlling a gas engine are applicable to the pump. Thus the inlet valve may be fitted with a throttle valve controlled by the pressure or height of the water, and either the mixture or the gas alone may be governed according to the power to be developed. There is, however, something to be said for allowing the pump always to work at maximum capacity, and then a float on the high-level tank may serve to cut off the ignition, and to switch it on again as the water rises and falls between two fixed levels. The methods of controlling the pump by altering its periodicity have already been referred to, and it is easy to arrange that a portion of the delivery pipe shall be cut out or put into action so as to alter its effective length. This may be done by valves, as shown diagrammatically in Fig. 3. Thus the longest pipe route between the chamber A and the high-level tank will be when valves B and C are closed and valve D open, and the shortest route will be when valves B and C are open and the valve D closed.

Ignition Apparatus.—The author has invented an ignition apparatus in which ignition is determined by the compression pressure reaching the maximum incidental to each particular charge. It will be sufficient to describe one form of the apparatus, which is shown in Fig. 4 (page 100), and is intended to work on the high-tension system with the use of an induction coil. The low-tension circuit supplying the coil is capable of being broken at three points by switches marked a, b, and c. When all three switches are closed simultaneously, sparking occurs. In the apparatus shown there is a piston d acted upon by the water in the chamber, so that the pressure which exists at any moment in the combustion chamber is transferred by means of a water connection to the apparatus, and acts upon the right-hand side of piston d, causing compression of the spring e and a movement of the piston rod to the left. The piston rod which projects outside the cylinder has attached to it one end of a band f, which passes over a pulley g, and has its other end attached to a spring h, and in turn the pulley g carries a switch arm j, which has its movement limited by two stops. When passing between these stops it rides over contact k, and closes the circuit so far as this switch is concerned. On the piston rod is a collar l, which at pressures below the desired range of compression pressures moves switch lever m and breaks the circuit at this point, and at pressures above the range of compression pressures moves switch lever n and breaks the circuit at this other point.

The action of the apparatus is as follows: At atmospheric pressure switch arm j is against stop p, switch b is open, and switch a is closed. As the pressure rises switch arm j passes over the contact to stop o, and on further increases of pressure switch b is closed by the action of its spring. This state of affair continues until the compression pressure has attained its maximum, and begins to decline slightly, the band in the meantime slipping round pulley g. As soon, however, as a very small decrease in pressures takes place, the friction of the band on the pulley causes the switch arm j to pass on to the contact k, and, the other two switches being closed, sparking occurs. The charge is thus fired, and the increase of pressure arising from the explosion causes the switch arm to pass to the stop o and also opens switch a. Expansion now takes place, and the switch arm passes from stop o to stop p as the pressure diminishes, and then switch a closes and b is opened, so that we again arrive at atmospheric pressure with everything in readiness to start a fresh cycle. In the type of pump already described the cushion pressure gives rise to another maximum; but this pressure being above the range of the compression pressures, switch a is then open, and the passage of the switch arm j over the contact k does not in this movement produce a spark. This ignition apparatus is applicable to all types of the author's pumps, and entirely safeguards any chance of pre-ignition, since ignition can only occur just after the compression pressure has attained its maximum. When the pump is to run at a steady load it is sometimes convenient to cut out the operation of the switch arm j and to set switch b in such a position that it closes just at the right compression pressure, or slightly before it is reached. In this case there is another spark produced on the cushion stroke, but as there is then no mixture to fire, it does no harm. The author has also invented an ignition apparatus which will produce a spark slightly before the maximum compression pressure, whatever this maximum pressure may be; but the apparatus just described has been found so satisfactory that it has been used throughout most of the experiments.

Two-Cycle Pumps.—The pump so far described is what may be called a four-cycle pump, because there are two outward and two inward movements of the column of liquid in each complete cycle. It would clearly be advantageous to suppress the cushion stroke and the suction stroke, and so produce a two-cycle pump. We are familiar with two-cycle gas engines in which outside pumps are used to draw in the gas and air and to force them into the working cylinder. But the production of a two-cycle pump is arrived at without any such complication, since no outside pumps are required. Up to the present, four types of two-cycle pumps have been constructed, and of these the simplest to explain is that shown in Fig. 5, where A is the combustion chamber fitted with an inlet valve B for combustible mixture, and exhaust valve C for burnt products. The bottom of the chamber is attached to a pipe having two branches D and E, and a single valve F which can close communication with either of the branches. One branch leads to a supply tank containing water at a level $x\,x$, the other branch leads to the delivery pipe and the high-level tank, and is fitted with a water valve G, which in this case is shown as closing a suction pipe dipping into a low-level tank H. When the valve F is in the position shown by full lines, and the compressed combustible charge exists in the top of the chamber A explosion takes place, and water is driven along the delivery pipe toward the high-level tank, the gases meanwhile expanding and imparting velocity to the column of water. When expansion has been carried to atmospheric pressure, the exhaust valve opens, and by this time the pressure on the left-hand side of the valve F will exceed the pressure on the right-hand side, and the valve will swing across so as to open communication between the combustion chamber and tank J, and to close communication with the delivery pipe. The moving column of water now has to entrain more water by sucking it up from tank H past valve G to follow the moving column. In the meantime the water level in the combustion chamber being

considerably below the water level in tank J, water will rise up in the combustion chamber, close the exhaust valve by impact, and cushion the burnt products imprisoned in the top of the chamber above this valve, until their pressure exceeds that due to the static head of the liquid in tank J. A reverse flow now occurs as the compressed cushion expands again, and a charge of combustible mixture is drawn into the combustion chamber. If there is still time for the action to take place, there will be a slight compression of the fresh charge by water again flowing from tank J into the chamber, but the main compression of the charge occurs when the column of water in the delivery pipe, having come to rest, returns, again closing valve G and forcing valve F from its dotted position back to the full-line position, thus giving free communication between the delivery pipe and the combustion chamber, and closing communication with tank J. When the water column has been brought to rest by expending its energy in compressing the charge, a spark at the ignition plug ignites the charge, and a fresh cycle is started. It is not necessary that the level of the water in tank J should be above the exhaust valve, because if it is at a level y y the oscillation which takes place from the tank to the chamber may still carry it far enough up the combustion chamber to close the exhaust valve. The return flow, which draws in the new charge will then be due to gravity, as the liquid in the chamber tends to regain the level of the water in tank J. It is desirable that a pump so constructed should have a dashpot to control the movements of valve F, so that it comes slowly on to its seat in the dotted position, and gives time for the water to be started in motion past valve G before communication with the combustion chamber is entirely cut off. If this valve is also controlled in its action of closing on its other seat, it may be arranged that the quantity of water which escapes past the valve back to tank J shall be equal to the quantity of water which moves from tank J to the chamber, and in this case the whole of the water delivered is drawn from tank H, and the returning column in the delivery pipe will then acquire a higher velocity than it would otherwise attain, and thus give a higher compression pressure.

A modification of this pump is shown in Fig. 6, which simplifies the arrangement and permits the use of any one water valve. In this case, between the supply tank and the combustion chamber, there is enough pipe to give a certain amount of inertia, and on this pipe is a standpipe, open at the top, up and down which the water oscillates. Suppose that explosion and expansion have occurred and water is being drawn past the valve A. It is clear that the supply will be drawn from the source which offers least resistance, so that the water contained in the standpipe will first flow past valve A, to be followed by water from pipe B, so soon as the greater inertia of this mass allows it to flow forward. When, however, the water in the pipe B has once been set in motion, its momentum keeps it moving, although valve A may be shut, so that it causes the level to rise in the standpipe even above the level of the water in the supply tank. This brings about a condition of affairs in which, when the water valve A again opens, the level of the water in the standpipe is considerably above the level of water in the combustion chamber. A quick rush of water, therefore, takes place, and the oscillation carries the water up the combustion chamber to close the exhaust valve. The necessary supply for this having come from the standpipe, its level is lowered until it is below the exhaust valve, and, consequently, gravity causes the level of water to fall in the combustion chamber and so draw in a fresh charge while the column of the water in the discharge pipe is still moving outwardly. The return of the column from the discharge pipe closes valve A and compresses the new charge ready for a fresh cycle.

Passing over a large number of modifications of the types of pumps so far dealt with, we come to a pump having two chambers, in which the explosions take place alternately. A diagram of this arrangement is shown in Fig. 7, and one of its chief differences from the other pumps is found in the fact that the introduction of the combustible charge does not depend either on cushioning or on an oscillation of the kind described. Both chambers are fitted with the usual inlet and exhaust valve, but a single water valve suffices to supply both chambers. Suppose all the valves are shut, and that in the first chamber there exists a compressed combustible charge, and that the second chamber is full of water. Explosion occurs in the first chamber, and water is driven downward and outward from this chamber toward the high level tank. As the gases expand a pressure is reached which can no longer sustain the water column in the second chamber, so that the water level in this chamber falls and a fresh charge is drawn into this chamber. When expansion is completed, we have, therefore, burnt products in the first chamber, a fresh charge in the second chamber, and water at a higher level in the supply tank than in either of the chambers. Consequently water flows from the supply tank toward both chambers and partially clears the first chamber of burnt products by rising to nearly the level of the water in the tank. Water has been entrained through the water valve to follow the column of water flowing toward the high-level tank, and as this column comes to rest and commences to return again, it closes the valve and flows mostly into the first chamber, from which the burnt products have a free exit past the exhaust valve. As the water reaches the exhaust valve, and shuts it, it finds only a very small cushion space in the top of this chamber, and its flow in this direction is therefore almost immediately arrested, so that the energy of the returning column is now obliged to expend itself in compressing the combustible charge in the second chamber. When this compression is complete, and the water once more at rest, the cycle is ready to be repeated by an explosion occurring in the second chamber. It will be noticed that when compression occurred the returning column had already moved some distance while exhausting products from the first chamber, and therefore it had an initial velocity when starting compression which causes the maximum pressure reached with this pump to exceed the compression pressures attained with the same head of water in the other types of pumps. This pump is therefore suitable for low lifts where high-compression pressures could not otherwise be obtained, and the gear required to operate the valves, although interlocking, is quite simple. A very powerful suction stroke is obtained in this pump, because there is a tendency to draw in a charge of combustible mixture equal in volume to that of the expanded products. Considerable throttling is therefore necessary, and it is very easy to work this pump on a small suction-producer plant offering high resistance to the passage of gas. It should be stated that this pump ran perfectly well at the very first attempt to start it.

The first pump invented and tested by the author was not one of those so far described, but was a two-cycle pump of more complicated construction. There were, as shown in Fig. 8, two water valves a and b in the supply pipe, one of which, a, was an ordinary mushroom valve, normally held closed by a spring, and the other a valve actuated by trip-gear when the velocity of the inflowing water reached a certain predetermined amount. The point of tripping was controlled by balancing the centrifugal force of the water flowing round a bend and acting upon a curved plate c against a spring d which tended to pull the plate into the stream lines. The trip gear was also utilized to open and shut the inlet and exhaust valves on the top of the combustion chamber. The action of this pump is as follows: When the column of water in the discharge pipe has returned to give the compression stroke, valve a is shut and valve b is open. Ignition now occurs, and the water is forced downward and outward from the combustion chamber, so that the column of water attains velocity, and as the expanded masses approach atmospheric pressure, valve a opens, and water is entrained to follow the moving column toward the high-level tank. Some water also flows into the combustion chamber, and discharges the burnt products. The rush of water round the bend in the supply pipe forces the curved plate into the recess, sets the trip gear, and opens the exhaust valve, thus allowing the inflowing water to drive out the whole of the burnt products. When, however, the velocity has diminished so that the curved plate can be pulled out by the spring, valve b is dropped, and the supply of water is cut off. At this time, however, the outwardly-moving column has not come to rest, so that its further movement may be utilized to draw water from the combustion chamber. This, in turn, will cause a new charge to be drawn into the chamber until the column of water ceases to move. The return flow now commences, and valve a, in shutting, opens valve b, compression occurs, and the cycle is ready to be repeated. The cycle of this pump is as theoretically perfect as any of the others; but difficulties were encountered in obtaining uniform working, and the experiments on this type were abandoned.

Pumps for High Lift.—When it is desired to lift water to a height exceeding the head equivalent to the mean pressure of the indicator diagram, an attachment is added at the end of the discharge pipe, as shown in Fig. 9. This addition may consist of a small air vessel placed at the end of the discharge pipe close to the large air vessel, into which the high-pressure water is to be delivered. The inlet into the large air vessel is fitted with a non-return valve, and the action, when working in conjunction with a two-cycle pump, is as follows: When the explosion occurs in the pump chamber the water is forced along the discharge pipe and rises in the small air vessel, gaining velocity and compressing the air therein until the rise in pressure is sufficient to open the valve. The energy of the water column is then spent in delivering water into the larger vessel, and any backflow from it is prevented by the valve closing. There is now sufficient energy stored in the compressed air in the small chamber to produce the return flow of the column toward the pump required to compress the next combustible charge; then the whole operation is repeated. The amount of air in the small vessel has to be adjusted according to the pressure in the large vessel, and the air may expand below atmospheric pressure on the return stroke.

Pumps as Air Compressors.—The extreme flexibility of the author's system is shown by the readiness with which it can be adapted to the case of compressing air. The column of liquid which reciprocates backward and forward from and to the pump can be made to enter an air-compressor chamber fitted with suitable valves attached to the end of what has so far been called the discharge pipe. The energy of the moving column of water is utilized to compress air, and also to store sufficient energy in an elastic cushion to produce a return flow toward the pump to give the compression stroke. This movement of the column also serves to draw a fresh quantity of air into the compressor. The action may be seen from the diagram of Fig. 10, where, for the sake of variety, the air compressor is shown attached to a four-cycle pump. The pump chamber A is connected to the compressor chamber B by means of the pipe C, and the quantity of reciprocating water is such that when the level is high in the pump chamber it is low in the compressor chamber. The air-compressor chamber is fitted with an inlet valve D, an outlet valve E, and two other valves F, G, which normally remain open under their own weight, and are so placed and constructed that they allow air to pass them, but not water, since the impact of the latter is sufficient to close these valves. Imagine that there is the usual compressed combustible charge in chamber A and a charge of air at atmospheric pressure in chamber B. Ignition occurs in chamber A and drives outwardly the column of water, so that the level rises in chamber B. Valve G, being open, allows air to escape to atmosphere while the gases are expanding and imparting kinetic energy to the moving column; but so soon as the level of water reaches the bottom of pipe H, which projects into the chamber, the water, trying to rise in this pipe, shuts valve G. The remaining air then suffers compression until the pressure at which the air is discharged is reached, when valve E opens and air is delivered under pressure. Next, the water reaches the level of pipe J, and, in attempting to escape with the air, shuts valve F. There being no further outlet, the imprisoned air is cushioned and the water column brought to rest. The cushion now expands again and gives a reverse flow, which drives out the products of combustion from the pump chamber, gives the cushion stroke in that chamber, and causes the cushion expansion and suction stroke which follows. All that has happened in the compressor chamber is that the water level falls, air is taken in and suffers compression again, but not to the extent which causes any air to be discharged. The pressure reached, however, is sufficient to give a second return flow and compress the newly-drawn-in combustible charge in the pump chamber, and the cycle is ready to be repeated. As the water level falls in chamber B, valves F and G fall by their own weight. It will be observed that by altering the extent to which pipe H projects into the air-compressor chamber the quantity of air acted upon may be varied, and this forms a ready means of adjusting the work of the compressor to deliver a greater quantity of air at a less pressure, or a less quantity of air at a greater pressure. Greater elasticity in meeting all possible conditions is provided in the case where water may be taken in or discharged at valves placed one close to the pump and one close to the compressor; but it would occupy too much time to deal with the very large variety of air-compressors which the author has invented in connection with his pumps. Naturally, the two-cycle pumps are better suited for this class of work than the four-cycle pumps, and it should not be overlooked as there is no solid piston, the space in the top of the air-compressor chamber may contain vertical sheets of wire gauze, which hold water and present a very large contact surface for cooling the air, and rendering the compression almost isothermal. The water which abstracts the heat does not remain in the chamber, for, in the case cited, where water valves are used, water is taken in and discharged at each cycle, and an automatic circulation through a cooling tank is set up. It is only necessary to make the tank of sufficient capacity to effect the required cooling.

(To be continued.)

Various experimenters have recently endeavored to determine the exact distribution of the magnetic lines of flux in the air-gaps of dynamos by means of testing coils. The author of a paper read recently points out that these methods give only approximate values, because the testing coils must have certain dimensions, and therefore give only the mean of the fluxes within the space coveted. The author shows how to apply a correction to change the curve which is experimentally plotted into a curve which represents more correctly the exact distribution of the flux.

COMBUSTION AND EXPLOSION.—I.*

A PRIMER ON EXPLOSIVES FOR COAL MINERS.

BY C. E. MUNROE AND CLARENCE HALL.

THERE is probably no activity of nature with which man is better acquainted or has been longer acquainted than with fire, of which he has made use from the earliest days for warming his body, cooking his food, giving him light, and in more recent times for breaking down rock, for making steam, and for other purposes. He has observed that a great number of substances can be burned, such as wood, charcoal, coal, sulphur, phosphorus, magnesium, zinc, oil and gas in their many varieties, and many others, and he has made use of them to produce heat and light. He has noticed that when wood is burned in large sticks it is difficult to start the fire, and that where there are but a few large sticks the fire burns but slowly. When the wood is cut into kindlings and these are heaped together, they burn more rapidly. When the kindlings are cut into shavings and these are piled together, they burn still more rapidly; and when the wood is cut into dust by means of a saw and this dust is suspended in the air and set on fire, it burns with explosive rapidity.

The same thing is found to be true of the other substances that burn under ordinary circumstances and are therefore called combustible. That is, the more finely divided they are and the more intimately this finely divided material is mixed with the air, the more rapid is the burning or combustion. This intimate mixture with the air is best attained with gases such as marsh gas (the fire damp found in mines), coal gas such as is used for lighting, and acetylene, or with vapors such as those from gasoline; and when these are thus intimately mixed with the air the combustion goes on so rapidly that it takes the form of an explosion. Although an explosion is thus easily produced by mixing gas or vapors and air in the right proportions, explosions may also be obtained by mixing combustible dusts with the air in the right proportions and igniting them; and therefore we are not surprised to hear that explosions have been occasioned by mixtures of sawdust or flour dust or starch or sugar or soap or coal dust with the air. Many explosions thus produced are very violent, and destroy life and property.

In each of the kinds of combustion or explosion that have been spoken of the combustible substance is mixed with air, and that the presence of air is necessary for the combustion is proved by the fact that when we cut off the air from contact with a burning body the fire goes out, or, as we say, we have smothered the fire.

The reason for this has been found in the nature of one of the several different substances that the air is composed of. This is the gas named oxygen, which is about one-fifth of the whole volume of the air. It is possible to separate this oxygen from the air, and when this has been done and burning bodies are brought into contact with this separated oxygen it is found that they burn much more rapidly than in air, and that the combustion is much more brilliant. By repeated experiment it has been proved that all ordinary combustion is caused by the combination of the combustible substance with this oxygen of the atmosphere. Air deprived of its oxygen will not support combustion or life.

In view of these facts, and in view, further, of the fact that there are other substances in nature besides air that contain oxygen and will give up this oxygen to combustible substances, it would seem probable that combustion could be brought about through the aid

GAS AND DUST GALLERY No. 1, PITTSBURG TESTING STATION.

EXPLOSION FROM COAL DUST IN GAS AND DUST GALLERY No. 1, PITTSBURG TESTING STATION.

* Abstracted from Bulletin 403, published by the United States Geological Survey.

of such oxygen-containing bodies; and this was long ago proved to be true. One of the first, if not the first, of such bodies that became known to man is saltpeter, also called niter, or potassium nitrate, which, because it occurs as a white efflorescence like frost on the surface of the soil in India, has been called India saltpeter, although it has been found to some extent in many parts of the world.

If solid saltpeter in the dry condition is mixed quite thoroughly with a solid combustible substance, such as charcoal, the mixture burns easily when once it is ignited. The advantage of such a mixture is that the oxygen which is to support the combustion is in close contact with the charcoal which is to be burned, and that, therefore, this substance or mixture can be ignited and will burn without contact with the air, and will so continue to burn until the charcoal is completely consumed. As a result of the burning of the charcoal or carbon with the oxygen of the saltpeter a gas is formed. As another result of the burning of this mixture of charcoal and saltpeter heat is produced, and this heat warms up the gas, so that if it is unconfined its volume becomes greatly expanded, and if it is confined it exerts pressure and does work. Hence, if such a mixture be burned in the bore hole of a rock, it may break down the rock, or in the barrel of a gun it will drive out the bullet.

It is found, however, that it is not easy to ignite such a mixture of charcoal and saltpeter, even when mixed in the best possible way, and to overcome this difficulty use is made of another substance that ignites easily, one which on burning gives out heat enough to ignite the mixture of charcoal and saltpeter.

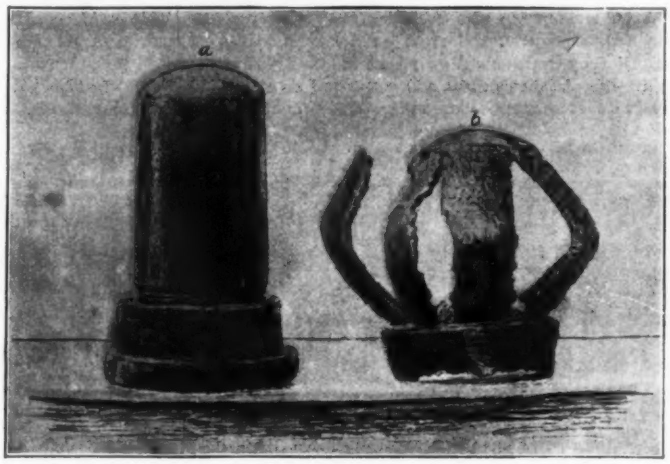
SCREENS FOR SEPARATING DIFFERENT-SIZED POWDER GRAINS.

This substance is sulphur, or brimstone, such as has been used in the past for the tips of sulphur or brimstone matches, for which the same object of easy ignition was sought. So eventually the mixture has been made of charcoal and saltpeter and sulphur, which are finely ground and closely mixed and then formed into grains, and such a mixture is called gunpowder. As has been pointed out, it is simple combustion that takes place when such mixtures are set afire, but on account of the thoroughness of the mixing, the proportions in which the different substances are mixed, and the way in which the material is finally made into grains, this combustion may proceed so rapidly that there is an explosion, which is powerful because the solid mixture, occupying a very small space, gives on combustion a large volume of highly heated gases.

About 1821 there was discovered in the desert regions of Peru and Chile another saltpeter, sodium nitrate, which has come to be known by the name of Chile saltpeter. Like the India saltpeter, potassium nitrate, it contains oxygen, and it will give up its oxygen to combustible substances with ease at a relatively low temperature. Hence a mixture of it with charcoal (known also as carbon) and sulphur makes a body similar to that produced with the India saltpeter, and since 1857 such a mixture has been extensively used, especially in this country, for blasting in rock and in mines.

Besides the India and the Chile saltpeters, many other solid substances that contain oxygen and will give up their oxygen easily, on heating, to combustible substances have become known, and many of them have been tried in the formation of the explosive mixtures. Though one or two of them are used to some extent, as will be shown further on, none are used so largely as the saltpeters.

It has also been found that we can get the oxygen out of the saltpeters in other ways than by heating an explosive mixture, as, for instance, by heating either

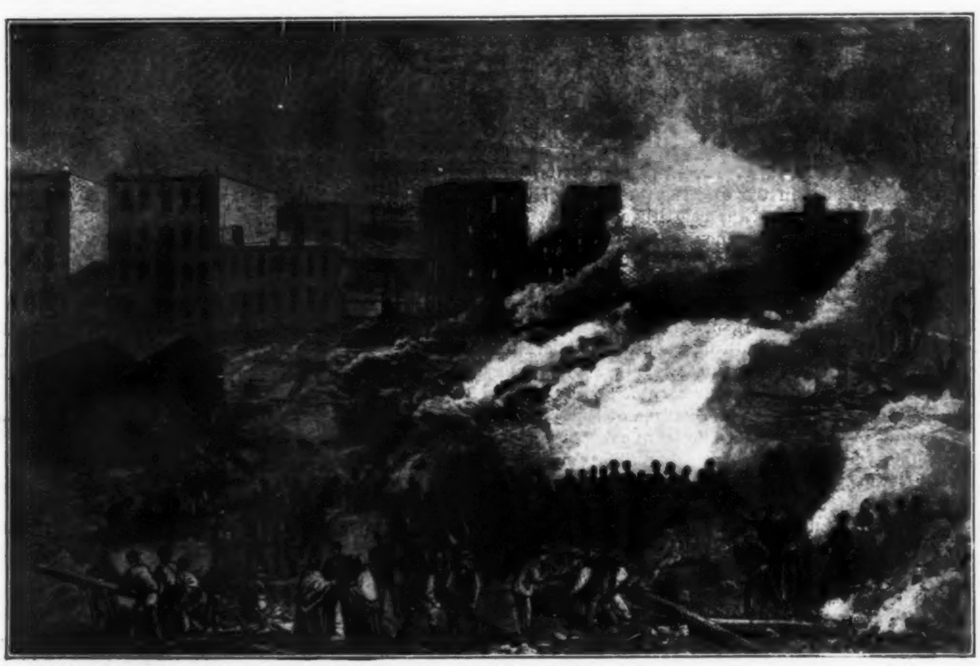


EXPLOSION OF HIGH EXPLOSIVE IN BOMB FILLED WITH WATER.

the India or the Chile saltpeter in a proper manner with sulphuric acid, when we obtain from them nitric acid, which contains all of the oxygen originally in the saltpeters. It has further been learned that when substances like cotton or starch or glycerin are treated with nitric acid in the proper way there are formed, from the cotton, gun cotton, or nitrocellulose, as it is also called; from the starch, nitrostarch; from the glycerin, nitroglycerin; and through this means the cotton, the starch, and the glycerin, which are all combustible substances, are converted into substances much more highly explosive and more powerful than mixtures made with the saltpeter and sulphur and combustible substances. In fact, such bodies can be made to explode by a shock such as is produced by a detonator or blasting cap when fired in contact with them, and the explosion is extremely rapid and very much more powerful than that of the saltpeter mixtures.

It has also been found that by the action of alcohol upon nitric-acid solutions of metals, such as copper or silver or mercury, under proper precautions, substances may be formed which are still more sensitive and still more violent in their explosive effects than guncotton or nitroglycerin. The best known and the most widely used of these substances is fulminate of mercury. When dry, this substance is so sensitive that a very slight blow, very little friction, or a slight rise in temperature will cause it to explode, and on explosion it produces a shattering effect upon any substance with which it is in contact. Moreover, the character of its explosion is such that if but a small mass of it is exploded in proper contact with guncotton or nitroglycerin or dynamite or other similar explosive, it will cause each of them to undergo a very violent explosion, which also will produce a shattering effect on the bodies with which they are in contact.

From what has been said it will be seen that there are at least two classes of explosives. One class is the saltpeter mixtures, in which an explosion is brought about by simple combustion that proceeds rapidly and gives rise to a large volume of highly heated gases, though almost one-half of the mass remains as a solid residue. Explosives of this class exert a relatively slow pushing effect upon the substances with which they are in contact when they explode, and are called "low" explosives. In the other class are explosives of the character of guncotton and nitroglycerin, which undergo explosion by being suddenly and wholly resolved into a large volume of highly heated gases, the change proceeding many times faster than the combustion that takes place in the saltpeter class of explo-



EXPLOSION FROM FLOUR IN MILLS AT MINNEAPOLIS IN 1878.

sives. Because of their speed and power these explosives have a shattering effect upon the substances with which they are in contact, and are known as "high" explosives, and also sometimes as detonating explosives.

Every explosive, when exploded, exerts pressure in every direction. When laid on top of a rock and exploded, gunpowder and other low explosives do not affect the rock, because they explode so slowly that the gases formed can lift the air above them and escape; but dynamite, fulminate of mercury, and other high explosives, if laid upon brittle or soft rock and detonated, may shatter it, because they explode so quickly that the gases formed cannot lift the large volume of air which confines them without pressing back forcibly against the rock. This confinement by air is not, however, close enough to give the best result with any explosive. By boring a hole in rock and tamping the explosive firmly in it, gunpowder and other low explosives may be made to break the rock, or a much less quantity of high explosive will break the rock than is required to break it when laid upon it. Confining an explosive is the cheapest and best way to use it.

It is foolish and dangerous for an inexperienced person to attempt to manufacture any kind of an explosive except under the supervision and direction of a trustworthy person who is skilled in the art. Many serious accidents, which have destroyed lives or inflicted injury on persons and property, have been caused by such attempts.

(To be continued.)

A NEW EPOCH IN NATURAL SCIENCE.

THE EARTH'S PENDULATION AND ITS EFFECT.

BY DR. LUDWIG STABY.

It has long been known that the earth's surface has experienced great changes, which have been manifested most clearly and strikingly by variations in the distribution of land and water. Extensive areas of the present land surface were once deeply submerged and former continents have vanished in the sea, leaving only their mountain peaks visible, as islands.

The study of fossil remains, and the effects of glacial action prove that the earth's surface has undergone great changes. Hence we speak of definite and successive geological periods. The change is still in progress. The areas of the oceans and the larger lakes are continually varying. In the North American chain of great lakes, for example, the water level is steadily rising (relatively to the shores) in the eastern lakes, Ontario and Erie, and as steadily sinking in Lakes Huron, Michigan, and Superior, the western members of the chain. Coral reefs are rising in some parts of the world and sinking into the sea in other parts. The Hawaiian islands are continually rising, while Helgoland is as surely sinking. These and many other remarkable and closely related facts have long been the objects of detailed examination and calculation but, until recently, no explanation of them has been found.

Now, however, an ingenious theory has been advanced to account for the changes in the earth's surface by Paul Reibisch, an engineer, and Prof. Simroth, a zoologist. The new theory, which is called by its inventors the pendulation theory, has already produced very surprising results and it appears destined to throw a flood of light upon this hitherto dark field of science and to furnish a very simple explanation of many puzzling facts.

Everyone knows that the earth performs two movements—daily rotation on its axis, which produces the phenomena of day and night, and an annual revolution round the sun, which causes the change of seasons. But, in addition to these two principal movements, the earth must oscillate in some way, in order to account for many indisputable facts, such as the gradual advance of the beginning of spring and autumn. The precise character of this oscillation remained unknown until Paul Reibisch undertook an elaborate and exhaustive calculation, which led him to the conclusion that the earth's poles are not fixed in the earth, but perform slow and regular oscillations in such a manner that the north pole, for example, moves gradually toward the equator along a certain meridian and, after a definite interval of time, returns along the same meridian to its mean position, and then proceeds to make a similar excursion on the opposite side.*

This regular oscillation of the earth's axis, although exceedingly slow—its period is calculated as at least 20,000 years—must produce great changes in the earth's surface. The displacement of the axis is equivalent to a change in the direction of rotation, which changes the direction of the centrifugal force at every point, and produces a tendency to flattening at the new positions of the poles and bulging at the new equator. The solid rock masses of the continents, in general, withstand this tendency, but the water promptly yields to it. Hence, if the north pole moves toward Europe, European waters flow southward and the northern part of the continent gradually rises higher above the sea level, while regions nearer the equator appear to sink. The result is an increase in the area of Europe and a shrinkage of South Africa. We are now living in a period in which the north pole is receding northward from Europe, so that the change now in progress is the reverse of that sketched above. Europe is apparently sinking and shrinking, as is conspicuously evident in the case of Helgoland, while the Hawaiian islands, under the influence of the opposite phase of the oscillation, are rising from the sea and increasing in area.

According to Reibisch's calculations, the poles oscillate along the meridian of the 10th degree of longitude east from Greenwich and its supplement, the meridian of the 170th degree west from Greenwich. These meridians form a great circle, which passes through Germany, Italy and Africa and which is called the circle of culmination or oscillation. The polar distances and the latitudes of all places situated exactly or this circle change more rapidly than those of any other points on the earth's surface, because the pole is moving directly toward or away from such places. The rapidity and extent of the changes of latitude at other points are inversely proportional to the distances of those points from the circle of oscillation. There are two points of the earth's surface at which no change occurs. These points are equidistant from the circle of oscillation and each of them is equidistant from every part of that circle. These two points would be called, in the language of geometry, the poles of the circle of oscillation, and Prof. Simroth has named them the poles of oscillation. One of these poles is situated in Sumatra, the other in Ecuador. These are the only points of the earth's surface that always lie on the ever shifting equator, which oscillates about the line that joins them. Hence they are always subjected to the maximum centrifugal force and the line that joins them should be the greatest diameter of the earth. The observed fact that these points are situated at the ends of the greatest diameter, therefore, affords a strong confirmation of the pendulation theory. The remarkable phenomena observed in the great lakes of America are explained by the fact that the chain is bisected by the meridian of Ecuador (80 deg. W. long.) so that the eastern lakes are nearer one half of the circle of oscillation (the meridian of 10 deg. E.) and the western lakes are nearer the other half (the meridian of 170 deg. W.). Hence the present movement of the north pole, which produces a decrease in latitude and a rise of water in the eastern lakes, produces an increase in latitude and a fall of water in the western lakes. The variations in height of coasts and coral reefs, and in area of continents and islands, in all parts of the world, can be explained in a similar way.

But these great geographical and geological effects of the earth's oscillation are vastly less important than the climatic changes caused by pendulation, for the moving pole carries the Arctic climate with it. These changes are greatest in places situated on or near the circle of oscillation (long. 10 deg. E. and 170 deg. W.), diminish with increasing distance from that circle, and vanish completely at the poles of oscillation. Hence the climate of Sumatra and Ecuador remains unchanged through all time.

When we reflect that all human culture and all animal and vegetable life are primarily dependent upon climate, we can form some vague idea of the tremendous effect produced in the organic world by the earth's oscillation. In the course of generations, both animal and vegetable species are compelled to adapt themselves to the gradual change in climate, to migrate or to perish. These three are the only possible solutions of the problem of existence. Animals which, like the huge saurians of the past, were unable either to adapt themselves to changed conditions or to migrate, have vanished from the face of the earth, while those which could migrate or adapt themselves have remained. As the climate changed most rapidly near the circle of oscillation, the general trend of migration must have been from that circle, eastward and westward, and toward the tropics. This explains the occurrence of like species in regions separated by extensive areas in which they do not occur, and the identity of the fauna and flora of tropical mountains with those of low-lying plains in the temperate zones. The development of the great variety of animals and plants that filled the earth in the different geological periods can be explained only by the geological and climatic influences of a series of periods of pendulation. The theories of adaptation and natural selection, introduced by Darwin, are confirmed and made clear by the pendulation theory, according to which species were evolved in the greatest variety and to the highest stage of development in regions near the circle of oscillation, while comparatively little evolution was accomplished in places far removed from that circle. Thus the flora and fauna of Australia still remain at a stage of development which was passed ages ago on the other continents, and present a singular survival of the forms of the tertiary period of geology, while western Europe and northern Africa, traversed by the circle of oscillation, have been the centers of creation of most of the animal and vegetable species of the eastern hemisphere. Prof. Simroth, in his book, gives an illuminating description of the distribution of extinct and living forms of animals and plants by the agency of pendulation.

Man is not exempt from the operation of the laws that govern other organic beings. Hence the cradle of the human race must be sought near the circle of oscillation and, as a matter of fact, all known fossil remains of primitive man and the anthropoid apes have been found near the 10th meridian of east longitude. Here, too, must be sought both the beginning of civilization and its highest development, and so we find the first rude drawings of the cave dwellers in the most enlightened countries, England, France, Belgium, Germany, and Austria-Hungary.

Hitherto the causation of the successive geological periods, including the glacial periods, through which the earth has passed, has remained an inexplicable mystery, but this mystery becomes as clear as day in the light of the pendulation theory. Each distinct geological period represents a period of pendulation, a complete oscillation of the poles of the earth. During each of these periods great changes were produced in the distribution of land and water, in climate and, hence, in the character and the distribution of organic species. The history of these changes is written in the succession of geological strata and the fossils which they contain, and the making of this history will continue as long as the earth shall endure.

The cause of this vitally important oscillation of the poles of the earth will never be known with absolute certainty, although many plausible hypotheses may be advanced. The oscillation may have persisted, though reduced in extent, from the time when the earth was a mass of liquid. Reibisch and Simroth conjecture that a second moon, which the earth once possessed, or some other small planet, came into collision with the earth in the region now occupied by Africa (so that that continent may be formed of the matter of the supposititious colliding planet) and that the impact caused the oscillation to which the name pendulation has been given. Whether this is, or is not, the true explanation, pendulation is certainly the result of cosmical events which will never be exactly known.—Illustrite Zeitung.

* Dr. Chanler in this country has proven such a theory mathematically.—Ed., Scientific American Supplement.

From results of a series of 30 tests made with 2¾ × 2¾ × 13¾-inch prisms of 1:2 Portland cement mortar, bonded at the ends and tested for flexure, it may be concluded with some degree of certainty: (1) That the bond existing between new mortar or concrete and old, where the old surface is smooth, is very slight. (2) That about one-half of the strength of the concrete is developed in a joint bonded (a) by roughening the old surface; (b) by applying a layer of cement paste; (c) or by providing the old surface with a bonding groove (in these tests, ⅞ × ⅞ inch). (3) That a large part of the strength of the concrete, perhaps as much as 90 per cent, is developed where the old surface is roughened and a layer of cement paste is applied. (4) That such a solution as "Ransomite" practically takes the place of the roughening, since a bond made with it is otherwise similar to the one made in these tests by roughening the old surface and applying a layer of cement paste.—Raymond B. Perry, in Engineering News.

NOTES ON HALLEY'S COMET.

INTERESTING FACTS ABOUT OUR CELESTIAL VISITOR.

PROF. E. E. BARNARD is probably the first astronomer who actually saw Halley's comet at this apparition, which was to be expected, since his vision is probably keener than that of any other American astronomer. Prof. Barnard picked up the comet with the 40-inch Yerkes telescope on September 16th. The following table, taken from Popular Astronomy, gives the various estimates of the diameter of the comet made by Prof. Barnard between September 17th and November 30th. The values must necessarily be discordant, but the mean will probably not be very far out:

OBSERVED DIAMETERS OF HALLEY'S COMET.

		"		Miles.	Weight.
1909	September 17	7.2		10,800	5
	24	11.1		15,900	5
	26	9.5		13,400	5
	October 17	10.0	±	11,200	1
	19	15.0	±	16,400	1
	26	15.0	±	15,100	1
	November 14	11.6		9,200	5
	Mean October 21			12,600	23

Hence its diameter at these observations is about one and one-half times that of the earth. Of course the diameter of the comet, when at its brightest, will vastly exceed this value.

The Rev. George M. Searle calls attention to the fact that Halley's comet on its way out from perihelion will make as near an approach to Venus as to the earth. The figures, also from Popular Astronomy, are as follows:

Heliocentric conjunction in longitude, May 1.82, G.M.T.

	Helioc. Longitude.	Latitude.	Radius Vector.
Comet	269° 44′	+9° 44	0.646
Venus	269° 44′	—0° 48′	0.727

The distance of the planet from the prolonged radius vector of the comet is probably too great to involve it in the tail, and the appearance of the comet, as seen from Venus, if there should be anyone to see it, would be very fine.

The spectacle will be interesting. The approximate geocentric positions will be, on the morning of May 2:

	α	δ
Comet	23h. 55m.	+8° 20′
Venus	23h. 43m.	—2° 40′

As Venus is very nearly of the same size as the earth, a good idea may be gained, from the view, of the relative dimensions of the comet and of our own planet. The moon will be up, but in the last quarter.

Halley's comet was not as brilliant as was expected in 1835, its last appearance. This was due very largely to the relative positions of the earth, sun, and comet rather than to any loss in brilliancy of the comet itself. It passed us about the middle of October on the way into perihelion, but at the time of perihelion and afterward was very far away, and on the other side of the sun, to which latter circumstance its failure in the way of tail may well have been due, as the tail was turned nearly away from us. At the time for the best development of it, the end of November and beginning of December, the comet was within a few degrees of the sun, as seen from the earth, and on the other side. There seems, therefore, to be no special reason to expect the appearance of Halley this time to be inferior to that of 1759, as the circumstances now are remarkably favorable, except those concerning the moon.

Halley's comet will brighten rapidly during February and March, and will undoubtedly become visible to the naked eye were it not coming nearer into line with the sun all the time, so that in March it will be in deep twilight. The comet is farther away than the sun, and will come into conjunction with it on March 25th. At the time of conjunction the comet will be about six degrees north of the sun. After conjunction it will come rapidly out of the morning twilight, and soon become visible to the naked eye toward the east for a short time before sunrise on each morning.

From L'Illustration.

On the night of May 18th, 1910, the earth will be immersed in the tail of Halley's comet. Twice in the last century a similar whisking of the earth by a cometary appendage occurred. In neither case was anyone the wiser until, long after, mathematicians revealed the fact. A comet's tail is so exceedingly attenuated that the vacuum in an incandescent lamp bulb is dense in comparison. Hence stars are seen through a comet's tail without diminution in brightness.

WHAT IS SCIENCE?

WHAT is the meaning of the word science? As in the case of so many words, its meaning has become confused by its partial applications, i. e., by its application to a part only of its contents, and this has often led to a misapprehension of the relation of science and of the scientific man to life. Science simply means knowledge, and to speak of scientific knowledge, as opposed to ordinary knowledge, is to use a redundant phrase, always supposing that we are using the word knowledge in its strict sense. Huxley defined science as organized common sense, by which, I take it, he meant knowledge of things as they are—knowledge the reality of which can at any time be checked by observation and experiment; for common sense, if it is anything, is the faculty by which we are made aware of reality. Science is sometimes spoken of as exact knowledge, but I am bound to say that I do not like the phrase exact knowledge; it seems to imply an insult to the word knowledge. Its use reminds me of a friend of mine who, when he was offered one morning at breakfast a fresh egg, mildly asked, "In preference to what other kind of egg?"

Scientific men are not a class apart and distinct from ordinary mortals. We are all scientific men in our various degrees. If this is so, how comes it that the distinction is so often made between scientific men and non-scientific men, between scientific knowledge and non-scientific knowledge? The truth appears to lie here: though it is true that all men possess knowledge, i. e., science, yet there are some men who make it their main business to concern themselves with some kind of knowledge, and especially with its increase, and to these men the term scientific has been technically applied. Now the distinctive feature of these men, in virtue of which the term scientific is applied to them, is that they not only possess knowledge, but that they make it their business to add to knowledge, and it is this part of their business, if any, which justifies their being placed in a class apart from other possessors of knowledge.

The men who make it their main business to add to knowledge may be divided into two classes, according to the motive which spurs them on. (1) There are those whose immediate object is to ameliorate the conditions of human life and to add to its pleasures; their motive is utility, and their immediate goal is within sight. Such are the great host of inventors, the pioneers in agriculture, in hygiene, preventive medicine, in social reform and in sound legislation which leads to social reform, and many other subjects. (2) There are those who pursue knowledge for its own sake without reference to its practical application. They are urged on by the desire to know, by what has been called a divine curiosity. These men are the real pioneers of knowledge. It is their work which prepares the way for the practical man who watches and follows them. Without their apparently useless investigations, progress beyond the limits of the immediately useful would be impossible. We should have had no applied electricity, no spectrum analysis, no aseptic surgery, no preventive medicine, no anæsthetics, no navigation of the pathless ocean. Some-

times the results of the seeker after knowledge for its own sake are so unique and astounding that the whole of mankind stands spellbound before them, and renders them the same homage that the child does the tale of wonderful adventure; such is the case with the work on radium and radio-activity, which is at present fixing the attention of the whole civilized world. Sometimes the work is of a humbler kind, dealing apparently with trivial objects, and appealing in no way to the imagination or sense of the wonderful; such was the work which led to and formed the basis of that great generalization which has transformed man's outlook on nature—the theory of organic evolution; such was the work which produced aseptic surgery and the great doctrines of immunity and phagocytosis which have had such tremendous results in diminishing human pain. The temper of such men is a curious one; no material reward can be theirs, and, as a rule, but little fame. Yet mankind owes them a debt which can never be repaid. It is to these men that the word scientific has been specially applied, and with this justification—they have no other profession save that of pursuing knowledge for its own sake, or, if they have a profession, it is that of the teacher, which, indeed, they can hardly avoid.—Prof. A. Sedgwick, in an address delivered before the Imperial College of Science and Technology.

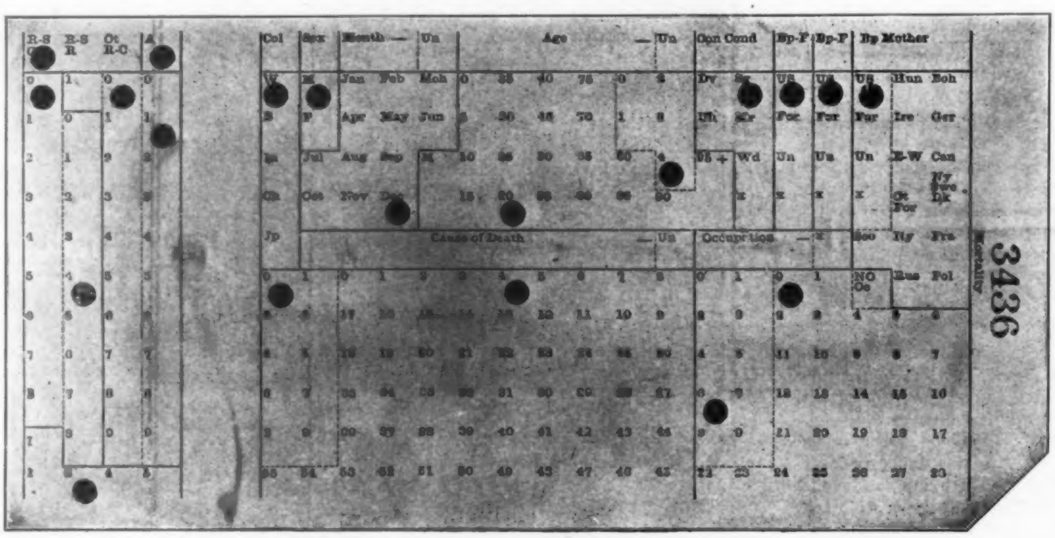
COUNTING OUR POPULATION BY MACHINE.*

A CARD CATALOGUE OF THE AMERICAN PEOPLE.

BY CENSUS DIRECTOR DURAND.

ACCURACY is the fundamental requirement of all statistical work. This means, first, accuracy in collecting the original material; second, accuracy in compiling and tabulating it; and, third, accuracy in analyzing and interpreting it. The first and the third stages in the process of statistical work are extremely difficult, and it is concerning these that I wish especially to speak. It is a matter of comparative simplicity to secure accuracy in compiling and tabulating statistics. The principal problem here is to secure economy of time and money. A few words only as to the methods of compilation and tabulation contemplated for the coming census will be sufficient.

The population census of 1910, like that of 1900, will be tabulated by the use of punched cards. Every person in the United States is given a card on which the facts with regard to sex, race, age, birthplace, birthplace of parents, and the like are indicated by the punching of appropriate holes. The number of persons possessing each specific characteristic or combination of characteristics which it is desired to show in the final tables is then counted by means of electrical tabulating machinery, electrical contacts being made through the holes punched in the cards.



ONE OF THE PUNCHED CARDS.

The punching machines to be used at the present census differ very radically from those used before, and will, it is believed, not only increase the rapidity of the work but tend to reduce the number of errors on the part of the clerks doing the punching. With the old punching machine, if an error was made in a single item—even though it might be the last item to be punched on the card—the entire card had to be destroyed. This consumed time and also resulted in a temptation to the operator to let the error go uncorrected. With the machines now to be used, no hole is punched in the card until the keys for all the facts to be punched have been set, and if the operator makes a mistake by depressing the wrong key he can correct it before the card is punched. It was not found possible at the last census to check all of the cards back to the schedules, and it will probably not be feasible to do so at this census. Part of the cards punched by each operator are selected at random and compared back, and if any appreciable percentage of error is discovered in those thus compared the other cards punched by the same operator are likewise compared.

The tabulating machines to be used at the present census will likewise result, it is believed, in a material increase of rapidity and reduction of errors. This is principally brought about by the fact that the results of the count for each unit of area are automatically printed, whereas formerly they were registered on dials from which readings had to be taken and recorded by hand. The reading of these dials took a large amount of time, during which the machine was idle, and inaccurate readings were not uncommon.

At the census of 1900 the agricultural data were also handled by means of punched cards. For each farm a large number of cards had to be punched, as the number of facts recorded regarding a farm was far greater than the number of facts recorded regarding an individual in the population census. At the present census it is the plan to do away with punched cards and probably to tabulate the data columns of figures by means of typewriters which also operate as adding machines, giving the total for each column. These typewriter-adding machines, as they are called, are a new device, of which there are several makes available. Aside from the minor advantages of having the facts all plainly recorded in typewriting so that they can readily be looked up and compared back with the schedules in case of apparent error, it is believed that a very marked saving in time will be secured in the editing of the returns for individual farms. Unfortunately, enumerators are bound to make a considerable number of errors in reporting farm data. For example, in reporting the number of bushels of grain raised on a farm, it is easy for an enumerator to leave off a cipher or add an unnecessary one, or to report a given number of acres in the crop without giving any product. Because of the delay and expense involved, it is not feasible to correct the great majority of these minor errors by correspondence with the enumerator or with the farmer concerned. It is necessary to make arbitrary corrections in the office. At the census of 1900 such minor errors were corrected by clerks examining the individual schedules, and a very large expense was involved. It is believed that by having the data for the various farms typewritten plainly in columns, the eye can run down these columns and discover such obvious errors with great rapidity, and it is hoped that several hundred thousand dollars of expense will be saved in this way.

The tabulation of the manufactures statistics is a comparatively small matter, since the number of establishments is but a small fraction of the number of farms covered by the agricultural census. The exact method of tabulating these manufactures statistics has not yet been determined.

Turning now to the more important subject of the means of securing accuracy in the original census returns collected in the field: It is self-evident that the entire value of the census depends on the securing of approximate accuracy in the original returns. Absolute accuracy is out of the question, and, in fact, a small margin of error does not seriously affect the value of the statistics, but any considerable margin of error practically destroys their value. No degree of accuracy in tabulating and no degree of skill and judgment in analyzing statistics can give value to data which were incorrect in the first place.

It has too often been a vice of statisticians to present to the public tables purporting to show all sorts of important facts, without due consideration of their truthfulness. The general public who use the statistics—in fact, even the trained statisticians who use them—have in most cases no means of discovering the inaccuracy of such statistics and go on using them in misguided confidence. The compiler of statistics has often been, unconsciously perhaps, careless as to their accuracy because of the lack of any possibility of detection. The man who has charge of the collection of statistical data ought himself to be the severe and uncompromising critic of those data. He alone has approximately adequate means of judging the degree of accuracy which has been secured; and it is his duty, having done all that is possible to eliminate error, to inform the public fully and frankly of the extent to which error presumably still persists. So far from taking advantage of the fact that others can not discover the errors which are hidden away in imposing looking totals, he should from that very fact recognize the more clearly his own duty to explain just how much or how little the statistics may be trusted.

This does not mean, of course, that the statistician who knows that there are certain errors in his figures should straightway declare them of no value. Statistics on certain subjects may be of very little value unless almost absolute accuracy is secured, but there are many subjects as to which close approximations to the truth are almost as valuable as the exact truth itself. It is the mark of the competent statistician to be able to decide approximately what the margin of error actually is, and also to what extent the error vitiates the results. As Josh Billings said: "It is better not to know as much than to know too many things that aint so."

At the census of 1900 and during the so-called intercensal period since that time, the Census Bureau has done a great deal in the way of criticising its own statistics in the manner I have suggested; but I doubt whether it has yet been sufficiently emphatic in cautioning the public with respect to the existence of un-

* Read before the quarterly meeting of the American Statistical Association, September 24th, 1909.

avoidable errors. A striking instance appears in connection with the manufactures statistics of the census. Although the reports in various places have called attention to the impossibility of securing bookkeeping figures from many establishments and the necessity of accepting more or less rough estimates, yet these same reports have published figures purporting to show the total volume of the manufactured products of the United States down to the last single dollar—$13,058,562,917 being the figures given for the total value of manufactured products in the United States at the census of 1900. Fortunately, the cents are not shown. The slightest consideration of the conditions under which a manufactures census is taken shows that the margin of error on a huge total like this may run into the tens of millions. Obviously the public should at least have the approximate character of such statistics constantly thrust before it by having them expressed in round figures. I think it desirable to express all very large totals of manufacturing statistics in millions, and in the case of the smaller figures which appear in the statistics for individual States and industries, to express the results in thousands.

To criticise statistics, however, is easy; the difficult task is to improve them. The Census Bureau will have done part of its duty to the public if it gives warning regarding the margin of error in the statistics it publishes, but it is far more important that it should reduce that margin of error.

There are two means to this end. The first and more difficult is to secure better men to collect the statistics; the second is to simplify and clarify the inquiries.

The statistics of population and of agriculture are collected by a different force from that employed in gathering the statictics of manufactures. The population and agricultural data are secured by enumerators, of whom there will be about 65,000 at the present census, they in turn being appointed by the supervisors, of whom there are about 330. The difficulty of securing competent and faithful enumerators is very great. The length of service is very short, 15 days in the cities and 30 days in the country districts. The period is thus too short to justify a man who

REAR OF THE NEW CARD-PUNCHING MACHINE.

has a good job in quitting it, while on the other hand it is too long in most cases to enable such men to get leave from their regular work to take the census. Moreover, the pay is small, averaging perhaps three dollars per day in the country districts and a trifle more in the cities, practically the pay of ordinary mechanics. Not only, therefore, are most of those who seek to be enumerators men who from financial motives are able to command only moderate pay in their occupations, but many of them are men who can not command regular employment and who are looking for odd jobs.

Consideration has been given by the census authorities from time to time to the plan pursued in Germany and some other European countries, by which census is taken chiefly or wholly by men serving without pay, who either volunteer their services from patriotic motives or who are required to act. I very much doubt whether conditions in this country are ripe for such a scheme. At any rate, nothing of this sort can be done at the present census. It may, however, be hoped that to some slight extent, and possibly to a considerable extent, men can be induced to accept the position of enumerator from interest in the work rather than for the compensation involved. I hope that a considerable number of colleges and universities of the country may see fit to give leave of absence to their students for the short time required to do this work of enumeration. The college student is a very useful enumerator in some cases, but it is exceedingly desirable that enumerators should actually live in the districts where they work, and there are multitudes of districts where no college students reside or where such students are in institutions hundreds or thousands of miles from their homes. Another class who can render good service as enumerators are school-teachers, but, with the enumeration taking place in April and May instead of June as formerly, few school-teachers can be spared from their duties to take the census.

The primary responsibility for securing efficient enumerators must rest with the supervisors of the census. It has been suggested from time to time that more efficient enumerators might be secured by competitive examination open to everybody. There is no doubt that if the expense and time required were not prohibitive, it would be advantageous to hold such an examination, although it would be necessary, instead of merely selecting those whose ranking in the examination was the highest, to refer all candidates who passed to the supervisor and allow him to select those whose personal characteristics, such as can not be tested by any written examination, were most suitable. The difficulty with such an open examination is the expense and delay involved. It is probable that for the 65,000 places there would be several hundred thousand candidates, and the grading of their papers would require a large force for a long time. At some future census this plan might be worth a trial, but it can scarcely be attempted at the present census within the limits of time and appropriations set by law.

The Census Bureau does, of course, undertake to protect itself against

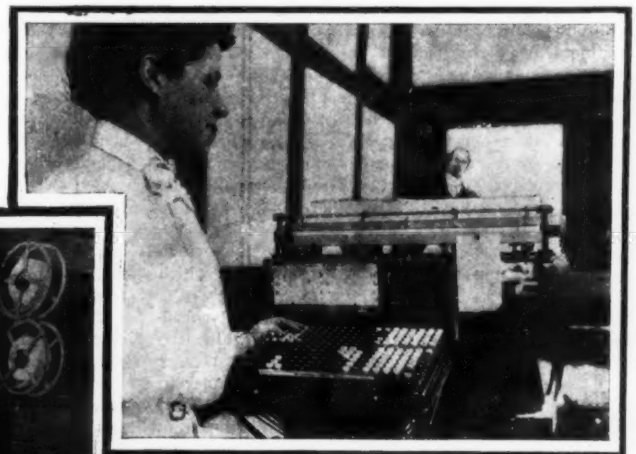
Photographs copyright 1909 by Waldon Fawcett.

THE NEW TABULATING MACHINE.

such obviously incompetent enumerators as the supervisors, through political influence or through oversight, may happen to choose. At the last census the enumerators recommended by the supervisors were all subjected to a test examination, and the same policy will be pursued this time. About one-sixth of the candidates selected by the supervisors were rejected as the result of this test in 1900. It may be wise to make the test at the present census a trifle more severe than at the twelfth census. At best, however, such an examination can do no more than to eliminate those who cannot write plainly and who are clearly lacking in an understanding of their duties. It can do little to assure the selection of men of industry, tact, or honesty. The judgment, efficiency, and integrity of the supervisors must be the prime reliance for securing enumerators who possess these fundamental qualifications.

I hope and believe that the supervisors at the present census are on the whole a higher type of men than those at any preceding census. The compensation offered to supervisors is somewhat more than ever before, but it is not really an adequate remuneration for men of the character needed. I believe that a very considerable proportion of the supervisors who have been appointed are men who in their regular occupations or professions are able to earn more than the supervisors' pay, and who have accepted the positions because of the honor and responsibility involved or from patriotic motives. There has, however, been no new departure with respect to the general method of selecting supervisors, save only that in large cities, or most of them, selections have largely been made independently of political recommendations.

The work of collecting statistics of manufactures and mining is in some respects even more difficult than that of collecting population and agricultural statistics. The number of employees required, however, is much more limited, and consequently it is possible to employ more elaborate methods of selecting them. The manufactures and mining statistics are practically all collected by men known as special agents. These are appointed by the director, and the law does not require any examination, but it is my intention nevertheless to make the appointments as the result of competitive examination from which, however, men who have had previous successful experience in field work for the Census Bureau will be excused, as well as men who have successfully passed the somewhat similar examination for the position of special agent in the Bureau of Corporations. It is evident that an ordinary civil-service examination, with its tests merely of what a man knows, is not adequate for the selection of men to do the responsible and largely independent work of visiting manufacturing and mining establishments to secure schedules from them. Consequently, following a precedent set by the Bureau of Corporations and to some extent employed also in other more advanced scientific civil-service examinations, the examination for special agents will consist in part of the presentation of evidence regarding the applicant's previous education and experience, while the remainder of the examination will be a very practical test of his ability to fill out a manufactures schedule. For those who are to do the simpler field work this test will be little more than reproducing on a schedule a set of facts



FRONT VIEW OF THE CARD-PUNCHING MACHINE.

which have been stated in narrative form, but for the agents who are to visit the more important establishments or who are to have charge of other agents, the test will consist of the filling of a schedule from somewhat complicated details in a hypothetical balance sheet, income account, and pay-roll. Moreover, not being bound by any legal requirement to take the man with the highest rating first, the appointing officers of the bureau will be able to give proper attention to such matters as personal address and tactfulness, which cannot be tested by any examination. We hope to secure as special agents largely young college and university men with some training in economics and statistics, or who have been bookkeepers of the more advanced type in manufacturing establishments or who have had other direct business experience.

PREPARATION OF SCHEDULES.

The form of schedules on which census statistics are collected has an extremely important bearing upon the accuracy of the results obtained. In the drafting of a schedule the first consideration is naturally what information it is desired to secure, but it is equally important to consider how far it is possible to obtain information accurately. There are always abundant suggestions from people interested in different economic and social problems as to points which ought to be included in the schedules, and there is comparatively little danger that a statistician in public office will neglect to make inquiries merely because he does not know that the information would be of utility to the public. There are not so many people, however, who are well informed as to the difficulties of securing statistical facts; and one of the most important tasks of the statistician is to determine what facts can be secured with accuracy by the means which he has at his disposal. Not only are some inquiries, which if answered correctly would furnish very valuable information, in themselves quite incapable of correct answer under existing conditions, but the multiplication of inquiries which separately are quite capable of accurate answer tends to lessen the accuracy of the replies to all of them. A schedule may, in other words, easily be overloaded. The enumerator or special agent collecting the statistics becomes discouraged if too much is asked of him, and the person to whom he addresses his inquiries becomes still more discouraged, not to say annoyed and confused.

Every reduction in the number of inquiries contained in a census schedule tends to greater accuracy in the

returns, except of course in those cases where such reduction in the number of inquiries obscures the clearness of the schedule. Some details in schedules, themselves comparatively unimportant, are often necessary in order to make clear what is intended to be included in a total.

This demand for reduction of the number of inquiries and simplification of them, in the interest of accuracy in the returns themselves, is in some cases opposed by the likewise important demand for details which will permit an accurate analysis and interpretation of the statistics. In other words, the lower form of accuracy sometimes stands opposed to the higher form, which seeks the true spirit of the phenomena investigated.

For example, take manufactures statistics. In many industries the entire technical and economic conditions are rapidly changing, and broad general interrogatories, even though answered with entire accuracy, give results which are not comparable with those of preceding censuses because of such changes in conditions. One instance of this character happens to have come to my personal attention recently. The schedules for the petroleum industry call for the value of the different kinds of oils produced, including the containers in which they are shipped from the refineries. Twenty or thirty years ago nearly all oil was shipped from refineries in barrels or other small containers, the value of which represented a large fraction of the total value of the product. At the present time the larger part of the products of refining is handled in bulk, without containers. A comparison of the average value computed by dividing the number of gallons into the total value of the product, including containers, from one census period to another is, therefore, highly misleading. The higher form of statistical accuracy practically compels the insertion of somewhat burdensome questions designed to separate the value of the product contained from that of the containers.

It is evident, therefore, that it is an exceedingly important and difficult task to frame a schedule which shall combine simplicity with that completeness which will permit correct interpretation.

The manufactures, mining, and agricultural schedules are necessarily the most complicated which the Census Office employs. The office has spent a very large amount of effort during the present summer in studying these schedules, and has called to its assistance a number of economists and statisticians from the universities, as well as men connected with the practical work of the Department of Agriculture and the Geological Survey and men actively engaged in business. I hope that we are succeeding in materially reducing the burden upon the enumerators and the special agents, while at the same time cutting out few inquiries of material value and adding some which will make results more intelligible.

To illustrate what has been undertaken, I will call attention to two very material changes which have been made in the schedule of manufacturers. At the censuses of 1900 and 1905 that schedule called for the average number of men, the average number of women, and the average number of children under 16 employed during each month in each establishment. To answer this interrogatory with strict accuracy would have required the special agent or the manufacturer to go in detail through every pay-roll of the year, usually either 52 or 26 in number, counting the number of men, women, and children separately on each—the segregation of those under 15 involving peculiar difficulty—and averaging the count for each month. To do this and at the same time to answer the inquiry regarding classified wages to which I will shortly refer would in my opinion have required ten times as much time as to answer all of the inquiries on the schedule put together. As a matter of fact, practically none of the returns were, I am convinced, based on analysis of the pay-rolls. They were in nearly all cases mere estimates made more or less offhand by the manufacturer or his bookkeepers, and, as many months had elapsed before the estimates were made, there is every reason to believe that they were often very wide of the mark.

The schedule as it has been revised for the present census calls for the number of men, women, and children employed during one specified week only, and for the total number employed, without distinction of age or sex, on the first pay-roll of each month. The relative extent to which women and children are employed will be ascertained approximately from the figures for the selected week. If the total number of employees on the first pay-roll of each month is returned with approximate accuracy, then the average of these twelve pay-rolls will unquestionably show very closely the true average number of employees during the year. We hope to be able to induce special agents and manufacturers in a large proportion of cases to answer this interrogatory from actual bookkeeping figures, and if we succeed, the greater accuracy will far outweigh any apparent sacrifices in the amount of information obtained.

At the last census of manufactures a question was included in the schedule which called for the number of employees classified according to their earnings for one week of the year, and separating men, women, and children under 16. This is a question which, if correctly answered, would furnish information of very great value. We have been convinced, however, that for many establishments correct answers cannot be obtained, and that for other establishments the amount of effort required to obtain correct answers is so great as scarcely to justify the expense, while also tending to injure the accuracy of all the data called for on the schedule. Strictly speaking, this inquiry falls within the field of the Bureau of Labor rather than that of the Census Bureau. It may be, however, that at another census, in order to take advantage of the fact that census agents are to visit every manufacturing establishment, we shall ask the authority of Congress to provide a special schedule covering classified wages, and an extra appropriation to cover the expense of getting it properly filled from actual pay-rolls. It would not be essential that returns of classified wages be secured from every establishment. If such returns could be secured accurately for even 50 per cent of the employees, they would be of very great value, and the agents should be specifically instructed to accept no estimates.

What has just been said regarding these two changes in the manufactures schedule will illustrate what I said before with regard to the increase in accuracy which can be secured by simplification of the schedules. The schedule of manufactures hitherto has been overloaded. Since special agents and the manufacturers who fill them were practically forced in many cases to make estimates in replying to the interrogatories regarding the average number of employees and classified wages, they were tempted to regard estimates as sufficient for the replies to all the interrogatories of the schedule. The intellectual integrity of the special agents was undermined by requiring of them work which they knew could not be done accurately within the time which they were allowed.

ANALYSIS AND INTERPRETATION OF STATISTICS.

It is a commonplace of statistical science that the mere presentation of figures has comparatively little value without analysis and interpretation.

The statistician owes to the public the duty of properly analyzing and interpreting his material, not simply in order that the public may get the full value of the results, but, what is more important, in order that false and misleading interpretations may be forestalled and prevented. Whether the untruthfulness has been due to intentional misrepresentation or to ignorance, census statistics have probably been made the basis of more fundamentally untruthful speeches and articles than any other set of facts. The reports of the Census Bureau in the past have contained many warnings against such misleading use of their contents, but such warnings are all too often disregarded. Liars and fools—to use perhaps exaggerted expressions—will continue to abuse census statistics, whatever the government may do to prevent it. We shall attempt at the present census, however, to make the warnings against such use of the figures even more numerous and more emphatic than in the past, in order that the man of ordinary intelligence may in general escape the pitfalls. Too often the warning has been posted in an inconspicuous place, hidden away in some long page of text, when it should properly have been presented in the most conspicuous place in the text, or even in the headings of the tables themselves, since most people, even those of considerable economic training, usually pay little attention to the text and assume that the tables mean what on their face they purport to mean. These warnings should relate not merely to inaccurate conclusions from the figures, but also, where necessary, should caution the reader against assuming a degree of accuracy in the statistics which does not exist. One of the most important duties of the census statistician is, as I stated at the beginning, to discuss frankly and clearly the margin of error in the returns.

In addition to increasing the frequency and the emphasis of the warnings against improper use of the census statistics, it will be desirable in my opinion to extend somewhat further than hitherto the analysis and interpretation of the statistics, at least in certain directions. A desirable feature of this increased analysis will be the publication of additional monographs dealing with particular economic and social problems. Many people have little interest in census statistics in general, but are profoundly interested in the data regarding some particular subject, and such data should be available for their use in separate form so far as possible. You will recall, for example, the exceedingly able monograph prepared by Dr. Willcox on the basis of the census of 1900 and dealing with the negro. We contemplate another monograph on this subject at the present census, and also similar monographs dealing with the foreign-born, with the family, with occupations, and perhaps with other similar subjects connected with the population statistics. Monographs dealing with particular branches of agriculture are also contemplated. The practice of presenting the statistics of the leading manufacturing and mining industries in monographic form has already been pursued quite generally at previous censuses.

Proper analysis and interpretation of the census statistics will call for the employment of a considerable number of statistical experts in addition to those on the permanent roll of the census. A considerable proportion of the tabular and text analysis and interpretation of the statistics at the previous census has been committed to men of comparatively little economic and statistical or business training and experience, although beyond question much of the work has been done by highly competent men. We hope to be able to enlist the service, for periods ranging from a few months to a year or two, of a considerable number of expert special agents to aid in the work of analyzing and interpreting the returns. Hitherto the limit of salary for temporary expert service of this sort has been altogether inadequate, $6 per day. In July of this year Congress passed a bill authorizing the payment of not to exceed $8 per day to 20 expert special agents. The director had asked that the limit of pay be fixed at $10, and it is possible that Congress will this winter be again urged to establish that rate. Even $10 per day is but moderate compensation to offer to men who possess the necessary qualifications for this work, most of whom are already earning at least that much in permanent positions.

It is not the intention to employ exclusively men who have had university training in economics and statistics in this advanced work of analyzing and interpreting the census material. Particularly in the case of the manufacturing, mining, and agricultural statistics, it will be desirable to obtain the service of men of practical business experience. This policy has been pursued, in fact, to a considerable extent at previous censuses. I believe, however, that in some cases the economy as well as the scientific value of this work has been impaired by having too much of it done by men who were not actually present in Washington but who gave only such time as they could spare from their regular professions or occupations to the work at their own homes, coming only occasionally to Washington for consultation. This practice has tended to undue lack of uniformity in methods and has placed too great responsibility on single individuals; while specialization has its great advantages, it should be combined with consultation with others working on kindred topics.

The general policy of insisting that, for the most part at least, the expert special agents who analyze the statistics and prepare the text of the reports shall be present in Washington at least the greater part of the time will in some cases exclude practical business men such as have formerly been employed for that purpose, because of their inability to give up, even temporarily, their regular duties. We shall, however, employ such men as consulting experts, having them come occasionally to Washington or sending the expert special agents who are assigned to particular tasks to consult with them at their homes. We believe that the undivided attention of men of high capacity and of general statistical and economic training, even though they may previously have had little direct experience in the particular subject entrusted to their charge, will enable them to become sufficiently expert in a comparatively short space of time to handle the statistics even more satisfactorily than can be done by men of more practical experience who are not personally present and can give only a part of their time.

A CENT'S WORTH OF ELECTRICITY.

At the average rate for power paid by the ordinary consumer, says Harper's Weekly, a cent's worth of electricity will operate a 12-inch fan for 90 minutes.

Will operate a sewing machine motor three hours.

Will keep a six-pound electric flatiron hot 15 minutes.

Will make four cups of coffee in an electric coffee percolator.

Will keep an 8-inch disk stove hot seven minutes, or long enough to cook a steak.

Will operate a luminous radiator eight minutes.

Will bring to a boil two quarts of water or operate the baby milk warmer twice.

Will make a Welsh rarebit in an electric chafing dish.

Will operate a 7-inch frying pan 12 minutes.

Will keep a heating pad hot two hours.

Will operate a griddle eight minutes.

Will run the electric broiler six minutes.

Will run a massage machine nearly four hours.

Will keep the dentist's electric hammer and drill going 90 minutes.

Will keep the foot warmer hot a quarter of an hour.

Will run an electric pianola one hour.

Will vulcanize a patch on an automobile tire.

Will heat an electric curling iron once a day for two weeks.

Iaque argentin is a metallic tin obtained by precipitating solutions of tin by means of zinc. With the addition of an adhesive it can be used for making silver coatings on paper, wood, and metals.

AEROPLANE ACCIDENTS.*

WHY THEY OCCUR.

The death of Delagrange, through the falling of his aeroplane, has two special features of technical interest. In the first place, it is the first fatal accident which has happened with an aeroplane of the monoplane type, and, in the second, it is the first which appears to be distinctly due to a failure in the main structure of the machine used. The first of the points just named is of considerable interest, from the fact that it seems to be generally assumed that, whatever other disadvantages it has, the biplane is a safer machine than the monoplane. Yet it is undoubtedly a fact that the greater number of accidents have happened to the biplane. Previous to the death of Delagrange there had been four fatal accidents with modern flying machines—viz., Lieut. Selfridge was killed when making an ascent with Orville Wright on a Wright machine in America; Lefebre lost control of his Wright machine, which therefore fell; Lieut. Ferber had a fall in his Voisin machine, from which he died soon after; and Fernandez was killed when flying in a biplane of his own design.

One at least of these—namely, Lieut. Selfridge's death—appears to have been due to the failure of the machinery, a broken propeller having been the primary cause of the fall. It is also possible that Lefebre's mishap was caused by the control-wire breaking, and the machine becoming unmanageable in consequence. It is, however, inevitable that in case of a fall the machine should be so damaged that it is impossible to tell what happened from the broken parts; and if the pilot is killed, it is difficult to ascertain how the accident took place. In the cases of Capt. Ferber and Fernandez there is no evidence that any part of the machine failed, and in the cases of Lieut. Selfridge and Lefebre the main framing did not fail. In the case of Delagrange's accident, however, there seems good reason to suppose that the main framing forming one of the wings gave way altogether, the machine falling in consequence.

Curiously enough, Santos Dumont had an accident the very next day from an almost exactly similar cause. In this instance the good fortune which has followed this experimenter throughout his aerial career continued, and he did not lose his life; but there is no doubt that the machine fell completely. In his case it is definitely stated that the accident was caused by the fracture of one of the wires which takes the upward thrust of the wing.

In the case of the biplane the top and bottom members are both of wood with wood struts, the whole being braced with very numerous ties of wire. In the case of the monoplane, however, the main spars of the wing are trussed to a strut below by a comparatively small number of wires. The structure of each wing is, in fact, very much like that of the mast and rigging of a sailing boat, the main spars taking the place of the mast, while the wire stays take that of the shrouds. A very important difference, however, is that the mast of a sailing boat is almost invariably provided with a forestay to take the longitudinal pressure when going head to wind, while the wing of an aeroplane often has no such provision, the longitudinal pressure due to the air resistance being taken entirely by the spar.

It is possible that this had something to do with the recent accident with which we are especially dealing, for the monoplane on which Delagrange met his death had been fitted with an engine of double the power originally provided by the maker, who is reported to have given this as the probable reason for the failure of the machine. As the new motor was of a very light type, the extra weight, if any, was quite a negligible proportion of the total weight of the machine. The vertical stresses on the wings and their supporting wires would therefore not be materially increased; but as the more powerful engine drove the wings a great deal faster through the air, the stresses brought upon them by the air resistance would be very considerably increased, and unless provision was made to meet this, the factor of safety would be very materially reduced. Whether the failure of the wing was actually from longitudinal stress or from the supporting wire breaking, as in the case of Santos Dumont, will probably never be accurately known; but it is quite clear that the question of ample strength to resist longitudinal stresses should be very carefully considered, especially when putting more power into an existing machine.

The question of the most suitable material and fastenings for the supporting wires is, moreover, a matter which requires very careful consideration. In the case of biplanes the wires are so numerous that the failure of one or even more may not endanger the whole structure, but those of the monoplane are so few that failure of even one wire may mean a broken wing. In this respect, as in others, the position is, in fact, exactly the same as the mast of a sailing boat, and one would expect, therefore, that the same materials would be suitable. At present, however, the stays of the aeroplane wings are almost invariably solid steel wire or ribbon, while the shrouds of a sailing boat are invariably of stranded rope, solid wire not having been found satisfactory. There is no doubt that, weight for weight, the solid wire will carry a heavier strain than the stranded rope when tested in a machine, but it is found in practice that it is not so reliable. The stranded rope seldom breaks without warning, but several strands go before the whole gets unsafe. As the breakage of these is very easily seen, an unsafe rope can always be replaced before actual breakage; whereas in the case of the single wire there is nothing whatever to show whether it has deteriorated or not.

It does not, of course, necessarily follow that what is most suitable for a boat is also the most suitable for an aeroplane, but as the conditions are so very similar, it seems very doubtful policy to use in an aeroplane what is not good enough for a boat.

Incidentally the Delagrange accident shows what may be the evil effects of striving after "records." What is wanted to make the aeroplane of practical use is that it should be reliable and safe. The tendency of record-breaking machines is the exact opposite of this, as the weights of all the essential parts must be cut down to the finest limits possible in order to provide enough engine power, gasoline, etc., for the record run. It is, in fact, generally found in engineering that the design and materials which will give the best results for a short time are essentially different from those which are the most reliable, and striving after records consists simply in neglecting reliability and safety to the utmost extent to which the pilots can be persuaded to risk their necks.

* Engineering, London.

THE COMMAND OF THE AIR AND ITS EFFECT ON LAND WARFARE.

The attitude of some of the continental powers as to flying machines for warfare, and the fact that much experimental work is being done in France and Germany, as well as in this country, justifies further consideration of the effect which aeroplanes and dirigible balloons may have on land warfare, a subject to which we referred in a recent article. The points of direct importance are as to what factors the ultimate command of the air will depend on, and what effect it will have on land warfare.

Taking the latter point first, we may probably quite disregard the idea of balloons being used to drop bombs into towns for the sake of wantonly destroying private property. It is quite true that a small amount of damage might be caused in this way, but it is not likely that it would be very great, certainly not enough to materially affect the issue of a war. Wanton destruction of private property has often been tried in warfare, but the effect has usually only been to embitter the struggles. There are, however, other and more legitimate ways in which the command of the air may probably be the deciding factor in a war. The first of these is the facility it gives for ascertaining an enemy's disposition and movements. This is of the utmost importance in war, and there is no doubt that a very large army might easily be completely paralyzed by a very much smaller one if the latter could always ascertain the enemy's movements without revealing its own. In fact, in many cases the amount of superiority which the force without flying machines would require from this cause alone would be overpowering. The position would, in fact, be the same as that of a blind man boxing against a man who could see. Besides getting information as to an enemy's movements, flying machines may be of enormous use in war by acting on an enemy's communications. A modern army, especially of large size, is absolutely dependent on its communications for everything that makes it of any use as a fighting force. The amount of food alone which is required is very large, and, of course, without this the army cannot live, let alone fight. But besides food, huge supplies of ammunition and stores of every kind are required. The expenditure of these gets greater every year, as the material of war gets more complicated, the rate of fire greater, and the expenditure of every kind more lavish, and without a steady stream of supplies pouring into it an army is helpless. Even in the American civil war, the Northern armies were often very much hampered by the raids of the Southern cavalry, who destroyed the railways, bridges, roads, etc., on which their supplies depended. The amount of damage which could be effected by cavalry would, however, be nothing to what could be done by flying machines, owing to the superior speed of the latter, the fact that they can move over any sort of country, and that probably much larger weights can be carried than could be on a horse. No doubt if communications were short, they could be protected by leaving enough men on them, but this means (1) that the army could never move far from its base; (2) that a very small proportion of the total army could be at the front. There would probably be many minor ways in which flying machines could also cause inconvenience and loss to an enemy.

One point of great importance is that the use of flying machines will render the command of the sea of much greater importance than it has hitherto been. So far command of the sea has given no direct power of attack on land, except the power of subjecting a very narrow strip of coast to gunfire. This is practically useless, and so the direct power of attack on land is *nil*. It is true that command of the sea has often decided a war by interfering with trade, and so bringing about exhaustion, and this result is accentuated by the fact that such command gives the power to land troops at any point without warning—a matter of enormous importance. The use of flying machines, in conjunction with command of the sea, will, however, increase the striking distance by the amount of the radius of action of the flying machine. There is no reason why the latter should not, in the future, start from a ship as well as on land, and therefore the fleet would form their base of operations. Thus, supposing that the flying machines were capable of flying 300 miles, it is obvious that they would have a striking distance of 150 miles from the coast in any direction, which might be a very serious matter for some nations whose military power is at present very great.

Obviously the way to combat flying machines will be to build opposing flying machines, and the command of the air will have to be fought for as has been the command of the sea. There will be fights in the air consisting of single engagements, and possibly of pitched battles between fleets of airships. What form the future fighting machine of the air will take it is impossible to forecast, and whether the navigable balloon will have any vogue, or whether the aeroplane will be universal, is doubtful. At present it appears as if the latter would be the case, owing to the aeroplane being faster, quicker at turning, harder to hit, and very much cheaper, the latter point always, of course, insuring a numerical superiority, with the same money spent on each type of airship.

While it is not possible to see what form the future flying machine will take, we can make some forecast as to what countries are likely to be most successful. The command of the air will depend on: (1) the men; (2) the material. Without men of nerve and skill to handle them, flying machines will be useless for fighting or any other purpose. Again, without the flying machines it is obvious that men cannot fly, and are therefore useless for air fighting. The position is, in fact, exactly the same as that of command of the sea. This has depended on men of cool daring to man the ships, combined with a well-trained industrious body of civilians at home to supply the ships, ammunition, and other necessary stores. As regards the men, fighting in the air will apparently need essentially the same qualities as are required for navigating and fighting on the sea. But however good the men are, they are quite useless without material. In the case of flying machines, as in the case of ships, this resolves itself simply into a question of money. Those who spend the most money are in the position to get the most numerous and best-equipped ships, and will be in the same position as regards flying machines. In the case of war in the air, as at sea, success will depend not only on plenty of material to commence with, but to supply the wastage of war, which is enormous, and gets greater and greater as the material gets more complicated and expensive. In all modern wars success depends even more on the civilians at home supplying the fighting force than it does on the actual fighting force itself; but on the sea this is far more the case than on land, and in the air will probably be more so still.

As far as can be seen therefore, the net result of war in the air will be to very greatly increase the offensive power of those nations which now have command of the sea, and to make the huge continental armies of very much less value than they have been. In fact, the time may not be far distant when no numerical superiority will avail against a small, well-equipped army, commanding the air.—Engineering.

THE INVENTION OF THE SLIDE RULE.[1]

Some modern writers attribute the invention of the rectilinear slide rule to Edmund Gunter, others to William Oughtred, but most of them to Edmund Wingate. This disagreement is due mainly to lack of opportunity to consult original sources. It is the purpose of this paper to demonstrate that Wingate never wrote on the slide rule, and that Oughtred is the inventor of the rectilinear as well as the circular type.

It was pointed out by Prof. De Morgan that Gunter invented Gunter's line or scale, but that he did not invent the slide rule. As Gunter's works are found in most large libraries, the correctness of this statement can be readily verified. This scale was not a slide rule, for it had no sliding parts.

No one denies that William Forster published in London in 1632 a book entitled "The Circles of Proportion," which described the circular slide rule invented by William Oughtred. In the dedication it is said that Oughtred invented also the straight-edge type; but this was not described until 1633, when Forster brought out an "Addition Unto the Use of the Instrument," with an appendix entitled "The Declaration of the Two Rulers for Calculation," which described the rectilinear slide rule.[2]

The question remains, Did Wingate invent the straight-edge slide rule, and is he entitled to priority over Oughtred? De Morgan maintained that Wingate never wrote on the slide rule,[3] but he had not seen all of Wingate's books. Thus he admits[4] that he had not examined Wingate's "Of Naturall and Artificiall Arithmetique," 1630, yet this very book is quoted by several recent writers as describing the slide rule[5]; but these and all writers who name Wingate as the inventor invariably fail to give evidence which would show that they had actually seen the book to which they refer. We have gathered information about all Wingate's mathematical books which De Morgan did not examine. We shall state where copies can be found, so that the data given here can be verified by those who are near the libraries named. We take up Wingate's books, one after the other, and show that none contains the slide rule.

(1) "L'Usage de la Règle de Proportion," Paris, 1624. De Morgan's assertion that this book describes nothing more than Gunter's scale [6] is corroborated by P. M. N. Benoit,[7] who examined copies in the Bibliothèque Nationale and the Bibliotheque Mazarine in Paris. There is a copy in the Bodleian Library.

Wingate brought out in 1626 in London a translation under the title "Use of the Rule of Proportion." Later editions appeared in 1628, 1645, 1658, and 1683. De Morgan saw the 1645 edition, a copy of which is in the British Museum. Wingate died in 1656.

(2) "Arithmétique Logarithmique," Paris, 1626. De Morgan described this book.[8] He saw also the "Logarithmeticall Table," London, 1635, which is anonymous, but is attributed to Wingate.[9]

(3) "Construction and Use of the Line of Proportion," London, 1628. Copy in the British Museum. The "line of proportion" here described is merely a mechanical table of logarithms. There are no sliding parts.

(4) "Of Naturall and Artificiall Arithmetique," London, 1630. Copy in the Bodleian Library. Describes only the instrument named in the preceding text. The first part of this book was enlarged by John Kersey the elder in 1650 under the new title "Arithmetique Made Easie." De Morgan saw the editions of 1673 and 1760.[10] The second part was re-edited by Wingate in 1652. Copy in the British Museum. The instrument described here is still the "line of proportion."

(5) "Ludus Mathematicus," London, 1654, 1681. De Morgan[11] inspected the first edition.

(6) "Use of the Gauge-rod," London, 1658 (second edition).

(7) "The Clarks Tutor for Arithmetick and Writing . . . Being the Remains of Edmund Wingate," London, 1671. Copies of both books in the Bodleian Library. Neither contains an account of the slide rule.

The longest masonry span in the world is said to be the Grafton Bridge, now being completed by the city of Auckland, New Zealand. It is 910 feet long and 40 feet wide, and the middle arch has a span of 320 feet, and a roadway elevation of 147 feet above the lowest part of the valley which it crosses.

[1] Abstract of a paper, by Prof. F. Cajori, read before the Section of Mathematical and Physical Science of the British Association, Winnipeg, August 27.

[2] For extracts see Cajori, "History of the Logarithmic Slide Rule." (New York: Engineering News Publishing Co., 1909.)

[3] "Penny Cyclop.," Art. "Slide Rule," and Wingate, Edmund, "Arithm. Books." Pp. 38, 42. (London, 1847.)

[4] "Arithm. Books," p. 48.

[5] A. Favaro in "Veneto Istituto Atti" (5), 5, 1878-9, p. 500; Mehmke in "Encyklop. d. Math. Wiss.," vol. i., p. 1054. (Leipzig, 1898-1904.)

[6] "Arithm. Books," p. 42.

[7] "La Règle à Calcul expliquée," p. vi. (Paris, 1853.)

[8] "Penny Cyclop.," Art. "Tables," p. 497.

[9] Loc. cit., p. 498.

[10] "Arithm. Books," pp. 48, 73.

[11] Op. cit., p. 44.

SCIENCE NOTES

It is ridiculous to say nowadays that the study of the humanities consists solely of the study of the writings and philosophy of the ancients; to take that view is to take the view of the schoolmen, the death blow to which was given by Bacon and Bruno. We have got beyond that; we claim that the true study of the humanities is a far wider thing—it is the study of the stupendous mechanism of the universe of which man forms a part, and the understanding of which is necessary for his happiness. That is the true humanity of which the other forms only a small portion. The time is coming when the principal preoccupation of man shall be the gradual disclosure of this mechanism, and his principal delight the contemplation of its beauty.

An interesting discussion aroused by the storm of September 25th, has been going on in Nature and elsewhere between Sir Oliver Lodge and Dr. C. Chree. The former claims that the phenomena are consistent with and strongly support the theory that such storms are due to the emission of vast multitudes of electrons from the surface of the sun during a solar eruption, as evidenced by the appearance of "spots on the sun." The stream of electrons, projected at an immense velocity in the form of a conical beam, has a magnetic effect calculated to be equivalent to that of hundreds of millions of amperes, and as the beam passes over or near the earth, the magnetic disturbances pass from positive, through zero, to negative. Dr. Chree points out, however, that the disturbances are not limited to the declination, as Sir Oliver appears tacitly to assume, but take place also both in the meridian and in the vertical component of the earth's magnetic force, and the storm does not correspond to a disturbing force in a fixed direction, waxing and waning, but is irregular and oscillatory. Moreover, the average duration of such storms is not 9 hours, but 30 hours. Dr. Chree does not combat or support the emission theories, but calls for reservation of judgment and minute study of the records with an unbiased mind.

Trained through long ages to believe that the heavens were the abode of the gods, who constantly interfered in the daily affairs of life and in the smallest operation of nature, it seemed to men impious to maintain that the earth was in the heavens, and to peer into the mysteries which surrounded them, and the endeavor to do so has been stoutly resisted; but the conflict, in so far as it has been a conflict with prejudice, is now over. It vanished in the triumph of the modern views on the origin of man which will be for ever associated with the names of Lamarck, Spencer, and Darwin. The triumph of these views does not mean that they are correct or that we know anything more about the great mystery of life than we did before. He would be a bold and a prejudiced man who made that assertion. What it means is this, that man is grown up, that he has cast off the intellectual tutelage under which he has hitherto existed, that he has attained complete intellectual freedom, and that all things in heaven and earth are legitimate subjects of investigation. But it means even more than this; it means that the conviction is rapidly growing upon him that the only way in which he can hope to improve his condition is by understanding the laws, physical as well as spiritual, under which he exists, and this he is determined to try to do by the only method open to him—that of minute and arduous research.

The Natural History Museum of Paris lately received a specimen of a new type of insectivorous animal coming from the western region of China. This region and also that of Thibet possesses many species of such animals, as Prof. Trouessart states in his paper on the subject presented to the Académie des Sciences, and most of them have been classified since 1870 and nearly double the number of generic forms. The scientist Armand David had discovered these specimens and it was thought that the list was complete. The present one, however, adds to the number, and it comes from the elevated regions of Moupin and Thibet, being sent to Paris by a missionary, M. Biet. It belongs to the family of porcupines, but does not possess quills, thus resembling the insectivorous animals of this family which are found in the Malay region. What is striking is that the new type resembles in its dentition certain small insectivorous animals which existed in France in the oligocene epoch. The forms of the present animal are considerably different from those of the porcupine. The animal is very light and is adapted for running and jumping like the Macroselides of Africa. It is a small animal about the size of the mole with long head and prominent nose in the form of a short trumpet, large ears and a long tail. In this respect it resembles the Podogymnura of the Philippines, recently described by Mearns. Its fur is soft and of a reddish brown with long black hairs projecting out, these being more abundant on the back. The present species inhabits Ta-tsien-lou in the province of Se-tchouen, at 2,545 meters altitude.

TRADE NOTES AND FORMULÆ.

Preparation for Soles of Boots (Hellor and Axler's). —To render the soles watertight, saturate and coat them with a mixture of 50 parts of linseed-oil varnish, 10 of water-glass, and 40 of Naxos emery.

Preservatives for Soles (Campe's).—For some years past Campe has saturated old boot and shoe soles with linseed oil varnish, coating new soles four or five times. A slight addition of copal varnish would probably increase the effect.

Pascal's Soup Extract.—Moderately boil vegetables in a double kettle for 6 hours and squeeze off the broth. Put some beef and bones in the latter and boil for 6 hours longer. Again squeeze out the fluid, and when it is cold remove the fat, portions of which should be added again later. Add 30 per cent of salt and boil down the whole till it is of the consistency of syrup.

Spence metal is employed for tightening water pipes and as a substitute for marble and cement. It cannot, however, be used as a substitute for lead plates for sulphuric acid chambers, for it is powerfully acted upon by nitro-sulphuric acid. The composition has a specific gravity of 3.1 to 3.7, and the melted mass hardens at a temperature of 182-183 deg. F., the fluidity changing to viscosity. To prepare the composition, dissolve 1 part of sulphur in a well-covered vessel and stir in 2 parts of finely powdered pyrites.

Substitute for Rubber.—Suffuse purified cherry-gum, chopped fine and previously washed with water, with three times its weight of water, and let it stand for a time, stirring frequently. Then pour off the clear solution and leave it to dry: a preparation similar to gum arabic will be obtained. Over the undissolved portion pour a liquid made of 10 parts caustic soda, 25 parts sodium carbonate, and 100 parts water. Put the mixture in a water bath and heat, with constant stirring, till it is dissolved, then dilute the liquid with water; treat, if necessary, with animal charcoal, filter and evaporate till the mass is dry, or till the residue can be spread on glass plates, putting the latter in a warm place to dry.

Semi-liquid Belt Dressing.—Dissolve together 6 parts pinoline, 2½ parts fish oil, 5 parts resin, and 2½ parts wool grease, adding 1 part mucilage and afterward 1 part of tallow, stirring the mixture. Now pour the mass into suitable vessels and keep on stirring till it gets cold. Belt dressing in sticks is compounded in the same way, but with the addition of 10 parts resin and 7 parts ceresine. The sheet-metal cases used for molds, provided with a stopper at one end, should be placed in a tub filled with water, and the mass poured into them. When the mass is cold the stopper is removed from the case and the stick, now finished, forced out by pressure. The sticks are then wrapped in tinfoil and packed in labeled cardboard boxes.

To Render Photographs Transparent.—Heat 10 parts (grammes) of paraffin and 10 parts (cubic centimeters) of linseed oil till the mixture begins to melt and dip the picture in it. Then place the picture between layers of blotting paper under pressure to remove any excess of the solution. Photographs treated in this way can be attached to glass by means of 100 parts (cubic centimeters) of a syndeticon (liquid fish glue) and 26 parts (grammes) of sugar. There are various kinds of paraffin, having different melting points, ranging between 86 deg. F. and 140 deg. F. It is well, therefore, in order to obviate superfluous heat, to heat carefully, and only till the paraffin dissolves and combines thoroughly with the linseed oil.

Waterproof Paint.—5,000 parts of chalk and 1,000 parts of zinc white steeped in 3,000 parts of water, to which 50 parts of alum have been added, mix with a glue solution of 750 parts of glue in 2,000 parts of water, constitute the body color. Coloring: Earth or metallic colors mixed with water: To the mixture add 2,000 to 2,500 parts of varnish and 7,500 parts of linseed oil, boiled with 330 parts of pale rosin, 330 parts of litharge, 50 parts of red lead, and 50 parts of umber, gradually adding 230 parts of zinc vitriol; finally add a solution of 350 parts of caustic potash and 350 parts of alum in 15,000 parts of water. After evaporation of a portion of the water, allow it to cool. After mixing with the priming, add 5 per cent of the weight in petroleum.

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